Dennis Kross / ED22

TECHNICAL NOTE

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FOR
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PRESSURE-SCALED WATER IMPACT TEST OF A 12.5 INCH-DIAMETER MODEL OF THE STS-1 SPACE SHUTTLE SOLID ROCKET BOOSTER (SRB)

FINAL REPORT

CONTRACT NAS8-33879

SHUTTLE

TECHNOLOGY

HUNTSVILLE ELECTRONICS DIVISION

CHRYSLER CORPORATION

ELECTRONICS DIVISION CHRYSLER CORPORATION

TECHNICAL NOTE

TN-SM-82-9

OCTOBER 1982

TEST REPORT
FOR
MSFC TEST #82-2

PRESSURE SCALED WATER IMPACT TEST
OF A 12.5 INCH DIAMETER MODEL OF
THE SPACE SHUTTLE SOLID ROCKET BOOSTER

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FOREWORD

This report represents results of pressure scaled water impact tests, using a 12.5 inch diameter model of the Space Shuttle Solid Rocket Booster (SRB).

The test were conducted in August/September 1982 by Chrysler Corporation, for NASA/MSFC at the Hydroballistics Facility of the Naval Surface Weapons Center, White Oak, Maryland.

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SECTION I - INTRODUCTION

Water impact tests using a 12.5 inch scale model of the STS-1 configuration Space Shuttle Solid Rocket Booster were conducted August/September 1982 at the Naval Surface Weapons Center, White Oak, Maryland.

The primary objectives of this SRB scale model water impact test program were:

Expand the full scale SRB design data base, for water impact dynamics and environments, from initial impact through cavity collapse, for the skirt internal components, proposed thrust vector control, external pod design, and effects of a 5-degree canted nozzle simulation.

A total of 59 tail first drops were made during this test. Model entry conditions simulated full scale vertical velocities of approximately 75 to 110 ft/sec with horizontal velocities up to 45 ft/sec and impact angles to $\pm 10^{\circ}$. These tests were conducted at scaled atmospheric pressures (1.26 psia or 65 mm.Hg).

This report contains a description of the model, test program, test facility, test equipment, instrumentation system, data reduction procedures, and test results.

SECTION II - MODEL DESCRIPTION

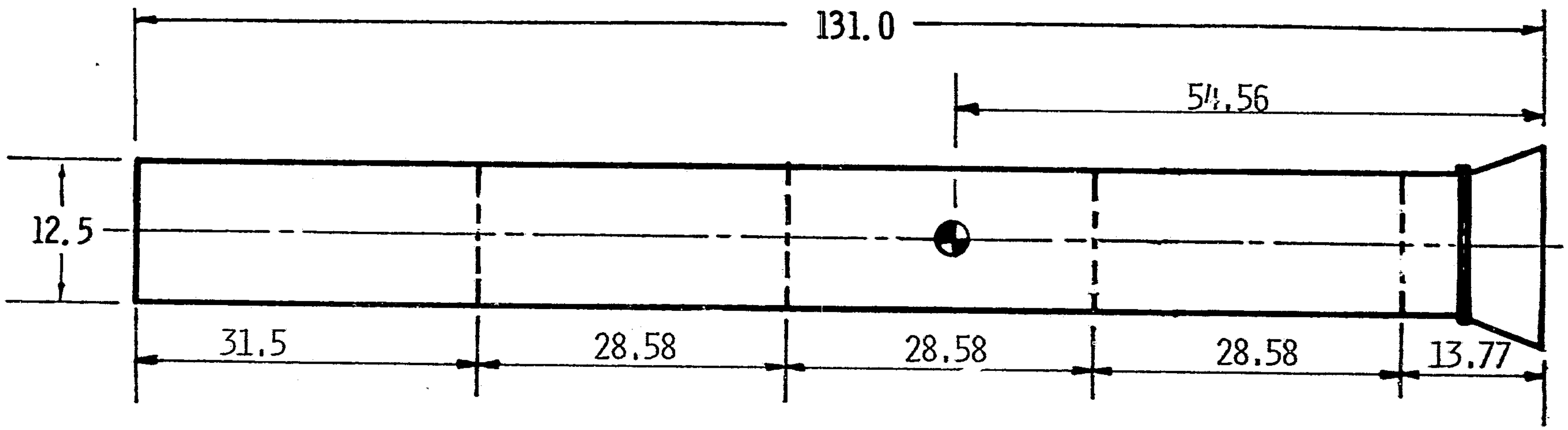
The model used for this test program was a 8.56% Froude scaled rigid body simulation of the STS-1 configuration of the Space Shuttle 146 inch diameter solid rocket booster. It consists of a 12.5 inch diameter cylindrical body section 123.2 inches long and a short 18^{0} flared skirt for an overall model length of 131 inches.

The forward end of the model is closed with a flat bulkhead and the aft end has a hemispherical bulkhead with a 3.9 to 1 area ratio nozzle. Figure I and 2 illustrates the model geometry and principal dimensions. This configuration represents the SRB with the nozzle extension jettisoned, except when noted otherwise (Config.II-5^{0} nozzle cant).

The model was fabricated from 2219 aluminum with a skin thickness of .08 inches. The forward cylindrical body sections were rolled and welded with machined flanges and stiffener rings at the end of each component. The aft body section, skirt, bulkhead, bellmouth and nozzle were machined from aluminum billets. The frontal area, geometry, and location of skirt stiffener rings were simulated on the model. After installing instrumentation and ballast the model had the following mass characteristics:

Weight ------------ 104 lbs
Moment of Inertia - 45.8 slug ft^2
CG Location ------- 54.56" from base

The above measurements were made without the instrument cable attached to the model. The instrument cable was supported independently of the model prior to each of the 59 drops, therefore no weight of the instrument cable is considered.



8.56% MODEL

WEIGHT = 104 LBS

INERTIA = 45.8 SLUG-FT^2

FIGURE 1. MODEL OVERALL CONFIGURATION

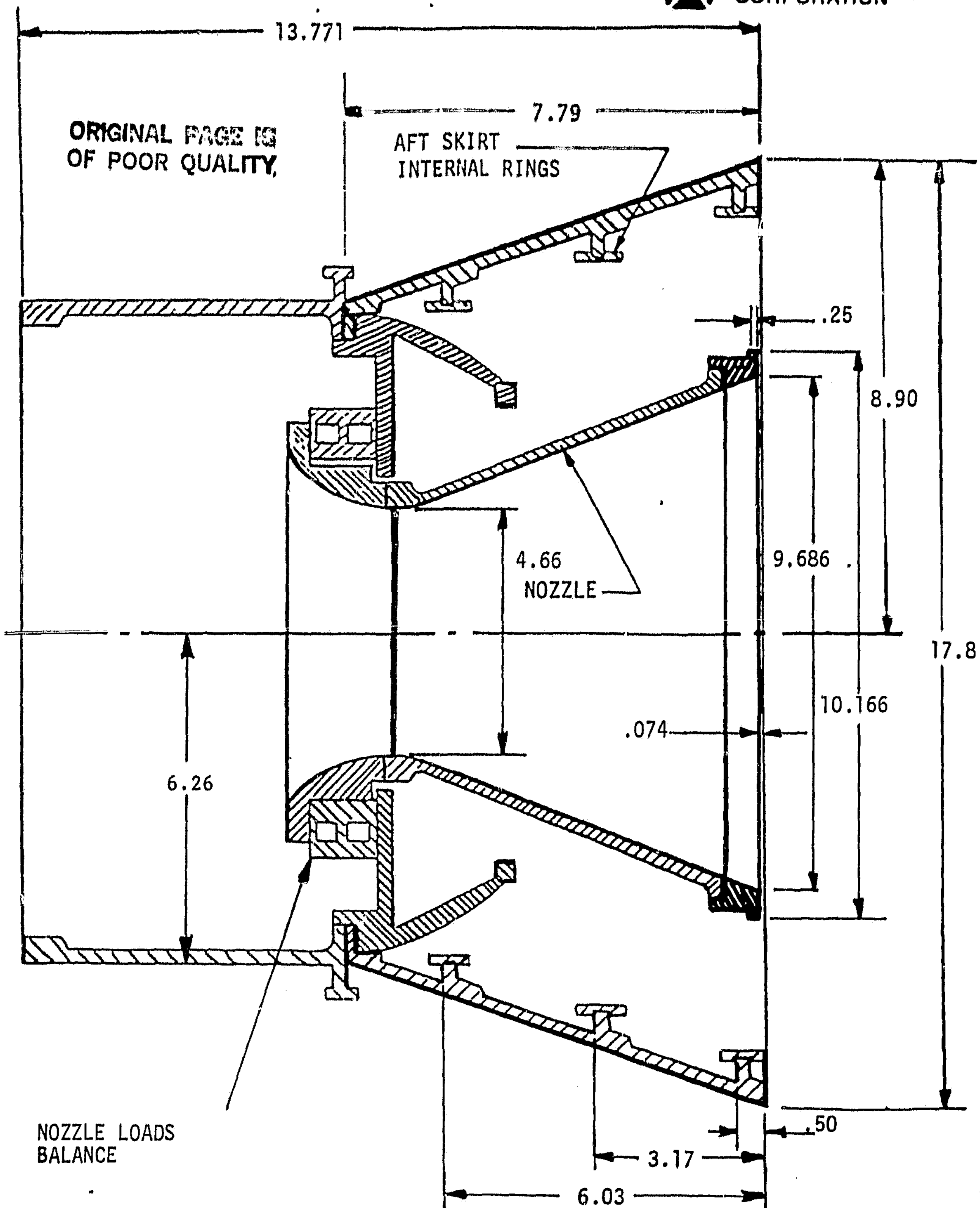


FIGURE 2. AFT ASSEMBLY (BARRELL) MODEL GEOMETRY

SECTION III - ELECTRICAL INSTRUMENTATION

The model was instrumented with 36 transducers. These consisted of 5 crystal type accelerometers, 27 piezoelectric pressure transducers, and a 4 component force balance which measured nozzle loads. These transducers along with their location and function are listed in Table III and illustrated in Figure 3 through 5. Only 26 of these transducers could be recorded during any particular test run.

Figure 4 shows model accelerometer locations. These consisted of axial, pitch, and yaw accelerometers. Three accelerometers were located at the model center of gravity and two on the aft bulkhead. Accelerometer sign convention is positive axial toward the model nose and positive pitch toward top centerline.

The model nozzle and bellmouth were attached to the aft bulkhead through a 4 component strain gage force balance. This balance encircled the bellmouth one inch forward of the nozzle throat and was of a moment cage design so that forces and moments are measured by individual strain gage bridges. This balance measured axial force, normal force, pitching moment, and yawing moment. All forces and moments are referenced to the balance moment center which is one inch forward of the nozzle throat and on nozzle ℄. Figure 32 shows the balance sign convention.

MEAS. NO.	MEAS. TYPE	RANGE	LOCATION	REMARKS
EA1	KISTLER SERIES 815A7 ACCELEROMETERS	500 G's	MID BODY - AXIAL	NOT RECORDED
EA2	↓	↓	AFT BODY - AXIAL	ALL RUNS
EP1			MID BODY - PITCH	RUNS 4 THRU 59
EP2			AFT BODY - PITCH	ALL RUNS
EY2			AFT BODY - YAW	ALL RUNS
SA1	BALDWIN SR4 STRAIN GAGES		NOZZLE LOAD - AXIAL	ALL RUNS
SN2	↓		NOZZLE LOAD - NORMAL	ALL RUNS
SP3			NOZZLE MOMENT - PITCH	ALL RUNS
SY4			NOZZLE MOMENT - YAW	ALL RUNS
D01	KISTLER SERIES 211B5	100 PSIG	TVC POD END - $\emptyset = 86^{\circ}$	ALL RUNS
D02	PRESS TRANSDUCERS	↓	TVC POD BOTTOM - $\emptyset = 15^{\circ}$	ALL RUNS
D03	↓		TVC POD SIDE - $\emptyset = 0^{\circ}$ (TDC)	ALL RUNS
D04			FWD RING BOTTOM - $\emptyset = 0^{\circ}$	ALL RUNS
D05			FWD RING BOTTOM - $\emptyset = 30^{\circ}$	ALL RUNS
D06			FWD RING BOTTOM - $\emptyset = 60^{\circ}$	ALL RUNS
D07			FWD RING BOTTOM - $\emptyset = 90^{\circ}$	NOT RECORDED
D08			FWD RING TOP - $\emptyset = 180^{\circ}$	NOT RECORDED
D09			MID RING BOTTOM - $\emptyset = 0^{\circ}$	ALL RUNS

TABLE I INSTRUMENTATION

MEAS NO.	MEAS TYPE	RANGE	LOCATION	REMARKS
D10	KISTLERS SERIES 211B5	0 - 100 PSIG	MID RING BOTTOM Ø = 30°	ALL RUNS
D11	PRESS TRANSDUCERS		MID RING BOTTOM Ø = 60°	ALL RUNS
D12			MID RING BOTTOM Ø = 90°	NOT RECORDED
D13			MID RING TOP Ø = 180°	ALL RUNS
D14			ACTUATOR MOUNT - Ø = 225° TANGENT	ALL RUNS
D15			ACTUATOR MOUNT Ø = 315° AXIAL	ALL RUNS
D16	KISTLERS SERIES 202A2	0 - 500 PSI	AFT RING BOTTOM Ø = 0°	RUNS 1 THRU 3 RUNS 33 THRU 59
D17				NOT USED THIS TEST PROGRAM
D18	KISTLERS SERIES 211B5	0 -100 PSIG	AFT SKIRT SKIN INTERNAL AFT Ø = 5°	ALL RUNS
D19			AFT SKIRT SKIN INTERNAL Ø = 0°	RUNS 1 THRU 33 ONLY
D20			AFT SKIRT SKIN INTERNAL Ø = 180°	RUNS 1 THRU 29 ONLY
D21			AFT SKIRT SKIN INTERNAL Ø = 180°	RUNS 1 THRU 29 ONLY
D22			EXTERNAL CASE Ø = 0° (TDC)	RUNS 1 THRU 31, 34 THRU 38, 40, 41, 42, 43, 44, 46, 51 THRU 56, 59
D23			EXTERNAL CASE Ø = 0° (TDC)	RUNS 1 THRU 30, 34 THRU 38, 40, 41, 42, 43, 44, 46, 51 THRU 56, 59
D24			EXTERNAL CASE Ø = 180° (BDC)	RUNS 31 THRU 33, 39, 43, 45, 47 THRU 50, 57, 58
D25			(BDC)	RUNS 32, 39, 43, 45, 47 THRU 59, 57, 58
D26			(BDC)	RUNS 30 THRU 38, 40, 41, 42, 44, 46, 51 THRU 56, 59
D27			AFT SKIRT EXTERNAL Ø = 180°	DITTO

TABLE I INSTRUMENTATION (Continued)

MODEL CONFIGURATION

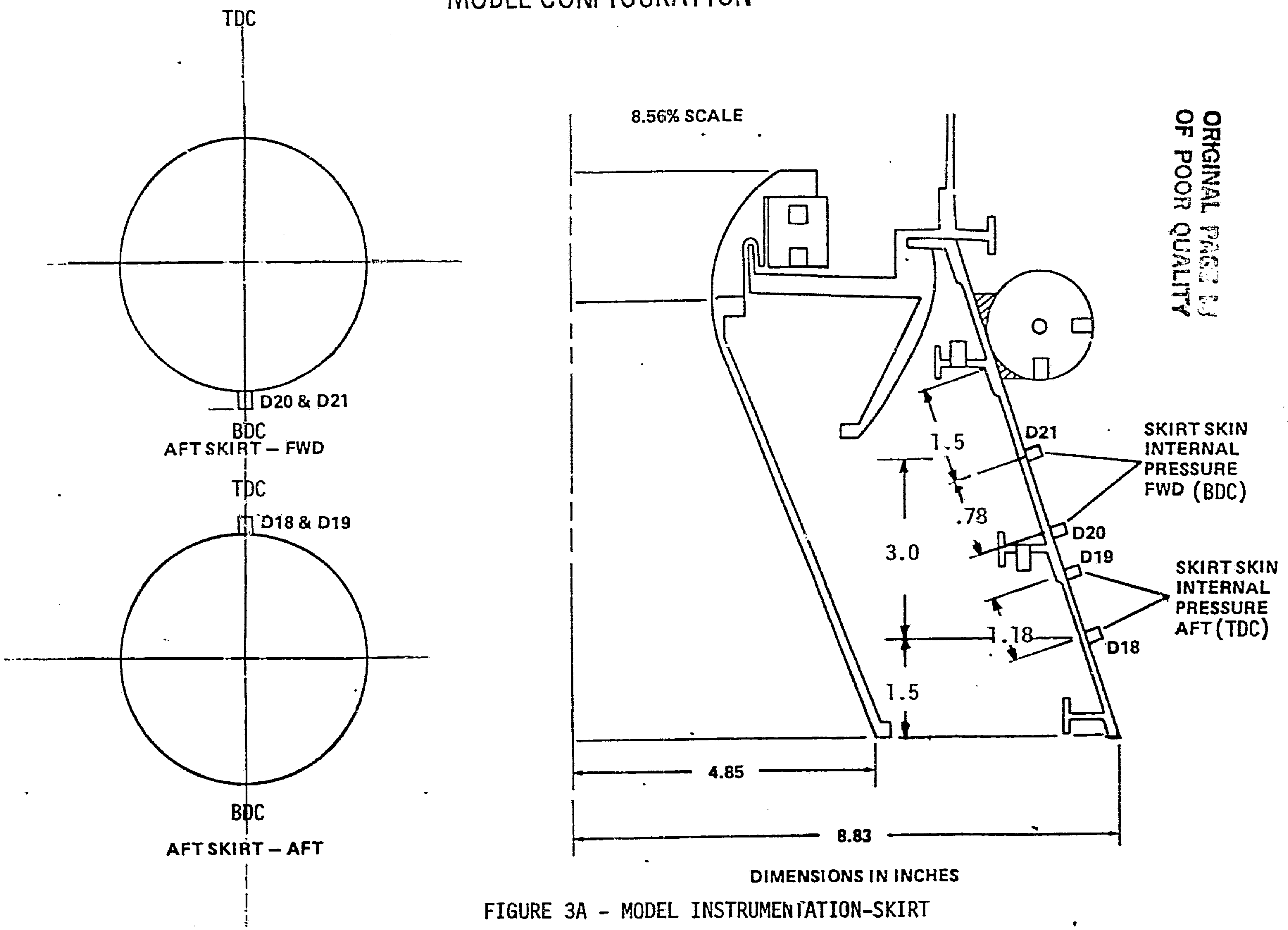


FIGURE 3A - MODEL INSTRUMENTATION-SKIRT

MODEL CONFIGURATION

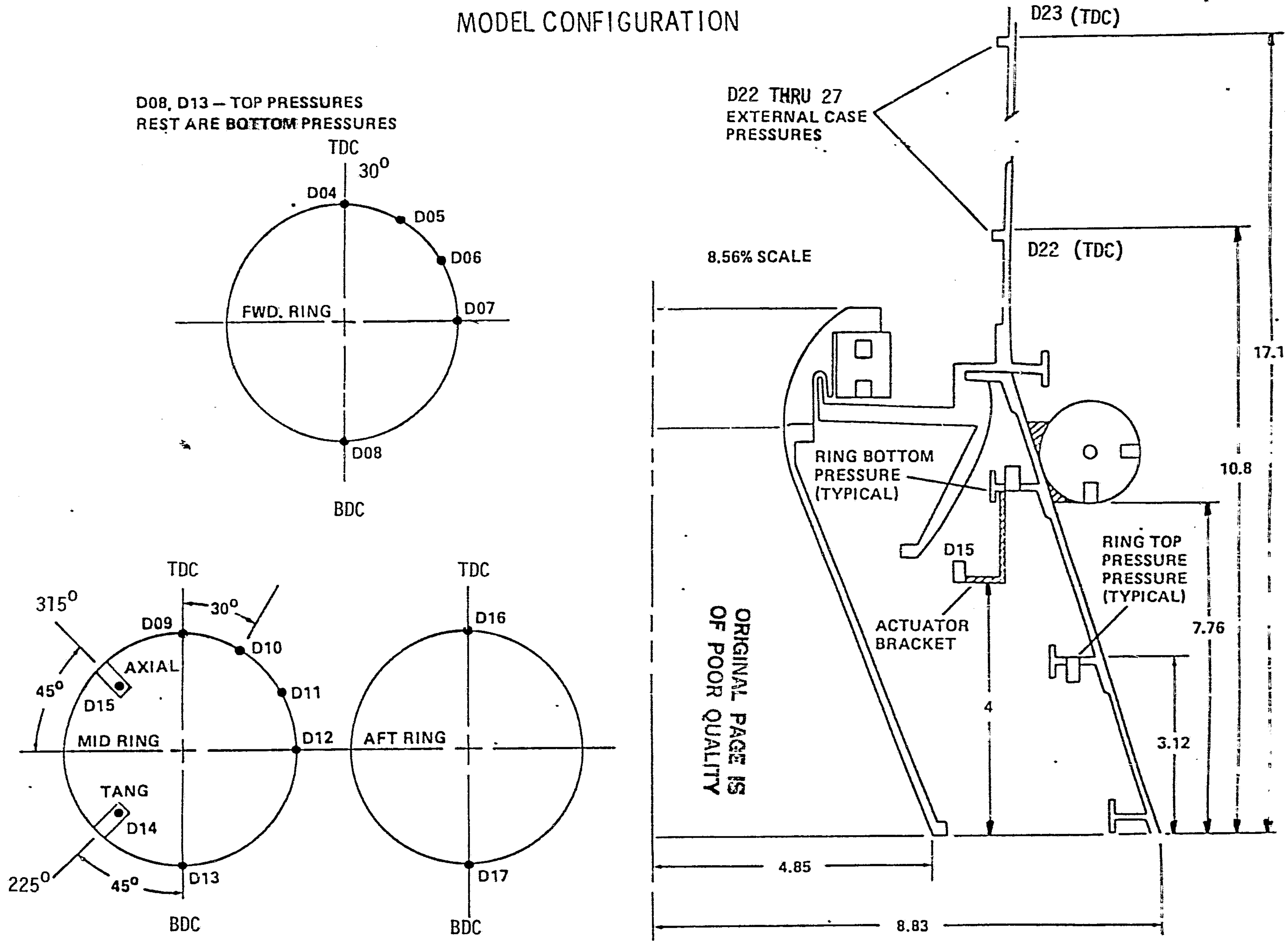


FIGURE 3B - MODEL INSTRUMENTATION-RINGS

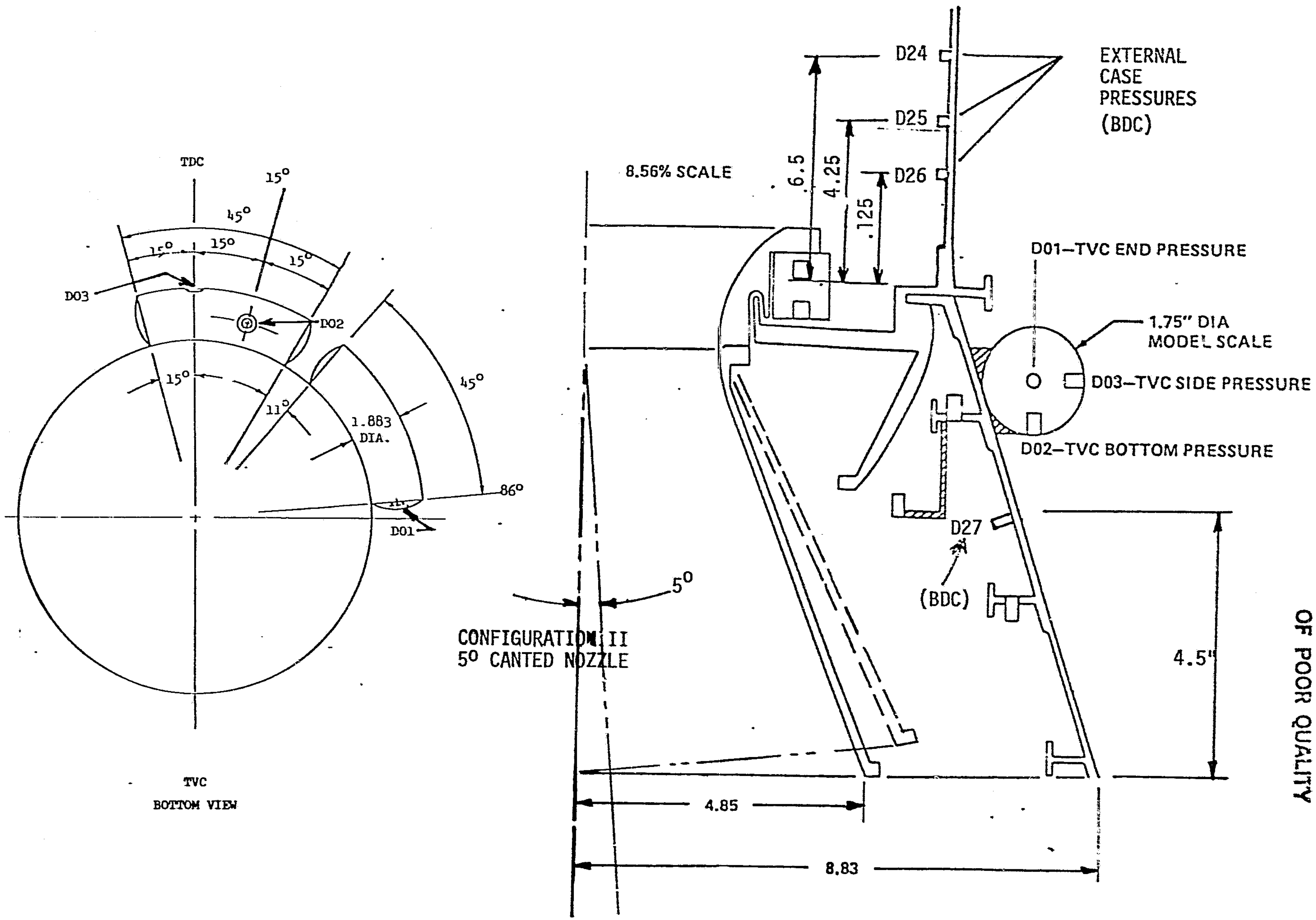


FIGURE 3C - MODEL INSTRUMENTATION CASE AND TVC

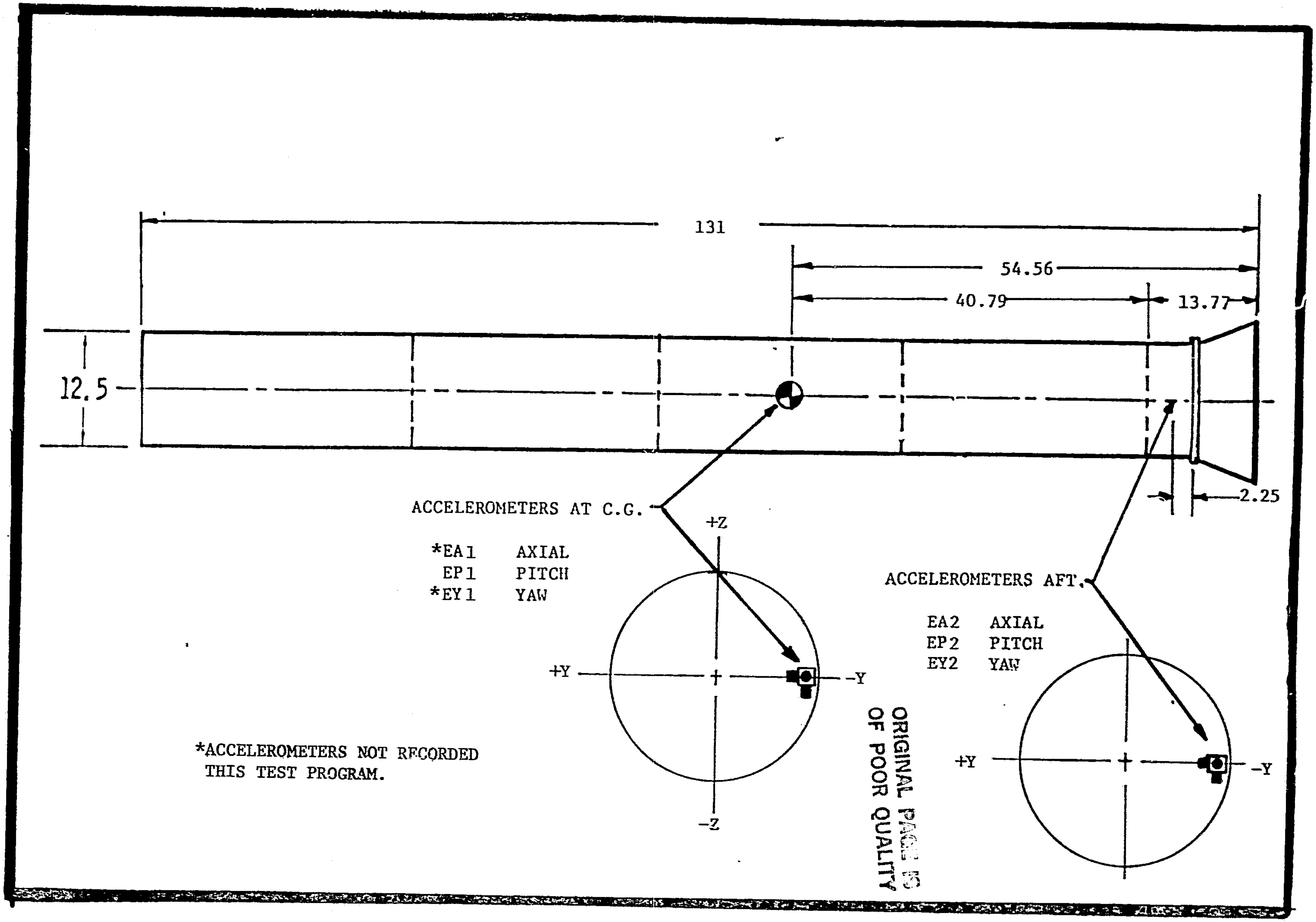


FIGURE 4. ACCELEROMETERS

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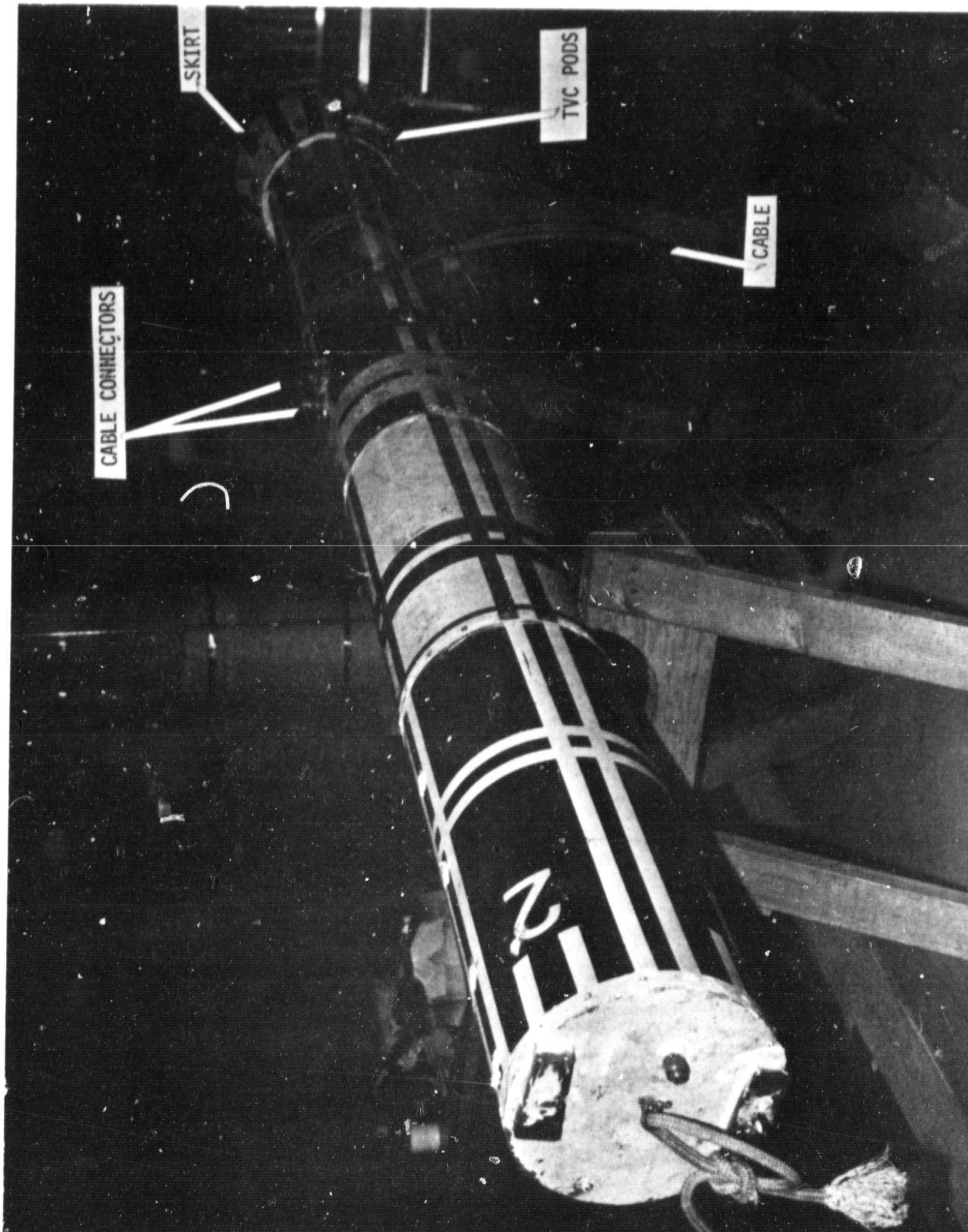

FIGURE 5A COMPLETE MODEL AND INSTRUMENT CABLE

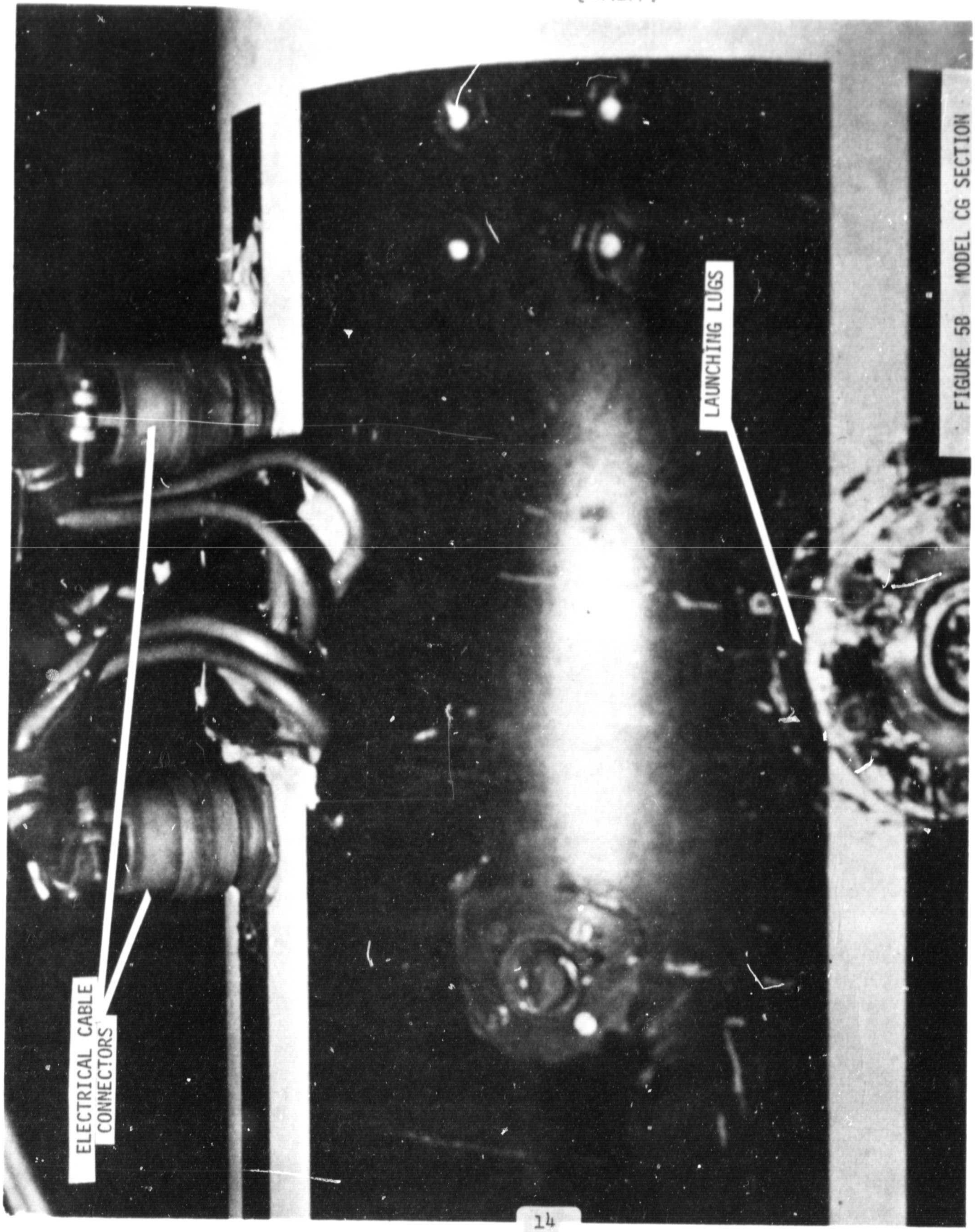

FIGURE 5B MODEL CG SECTION

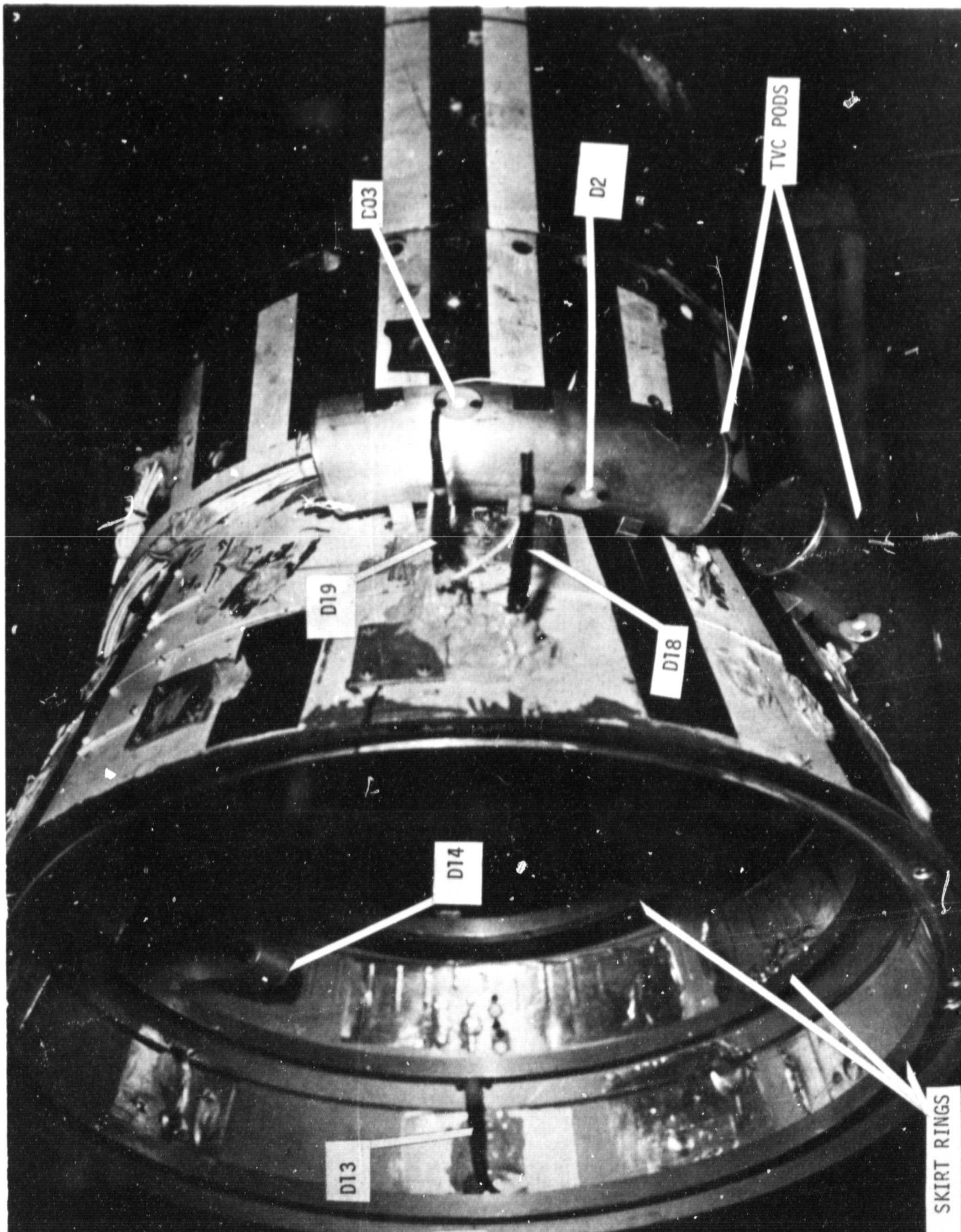

FIGURE 5C MODEL AFT SKIRT SECTION

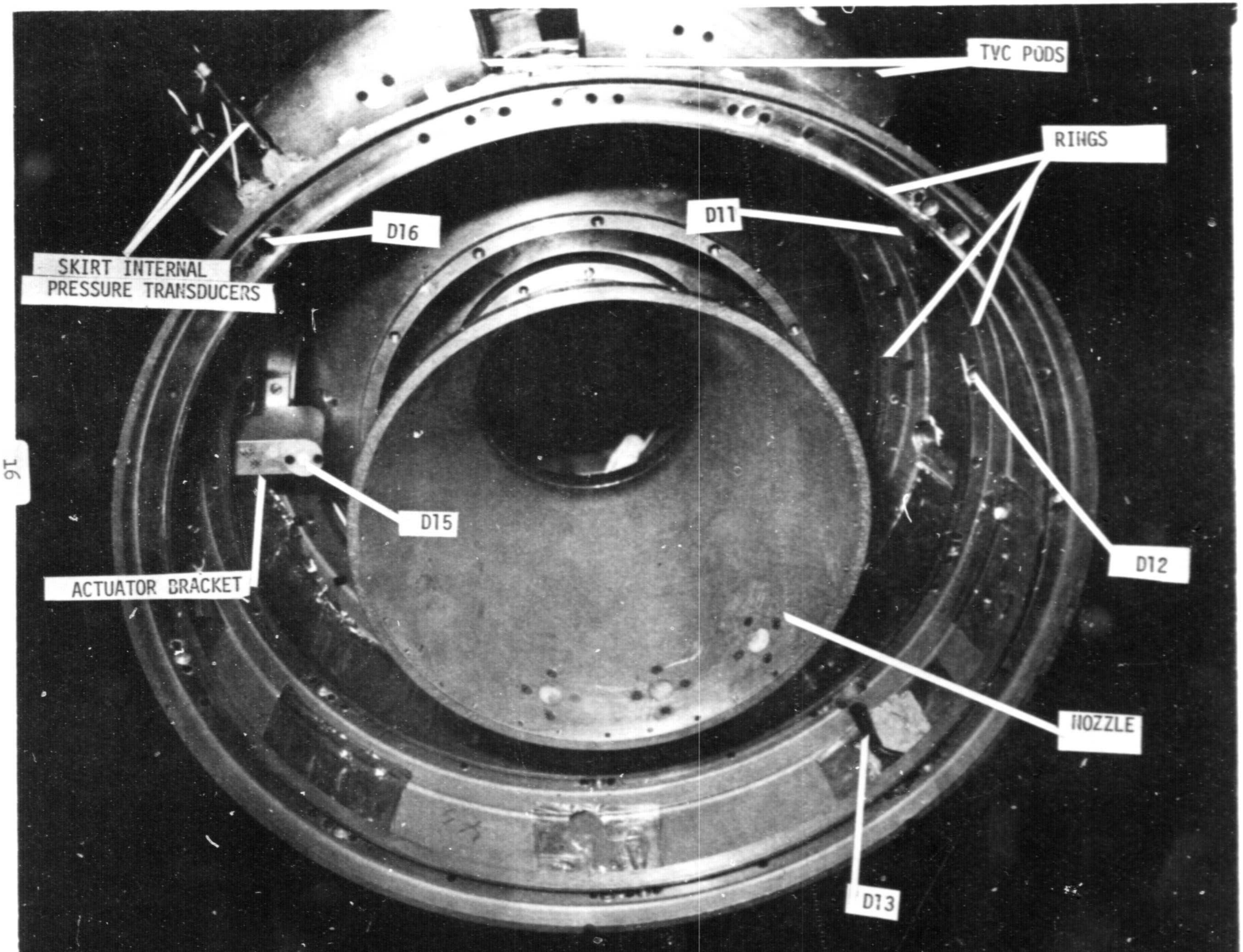

FIGURE 5D MODEL AFT SKIRT SECTION

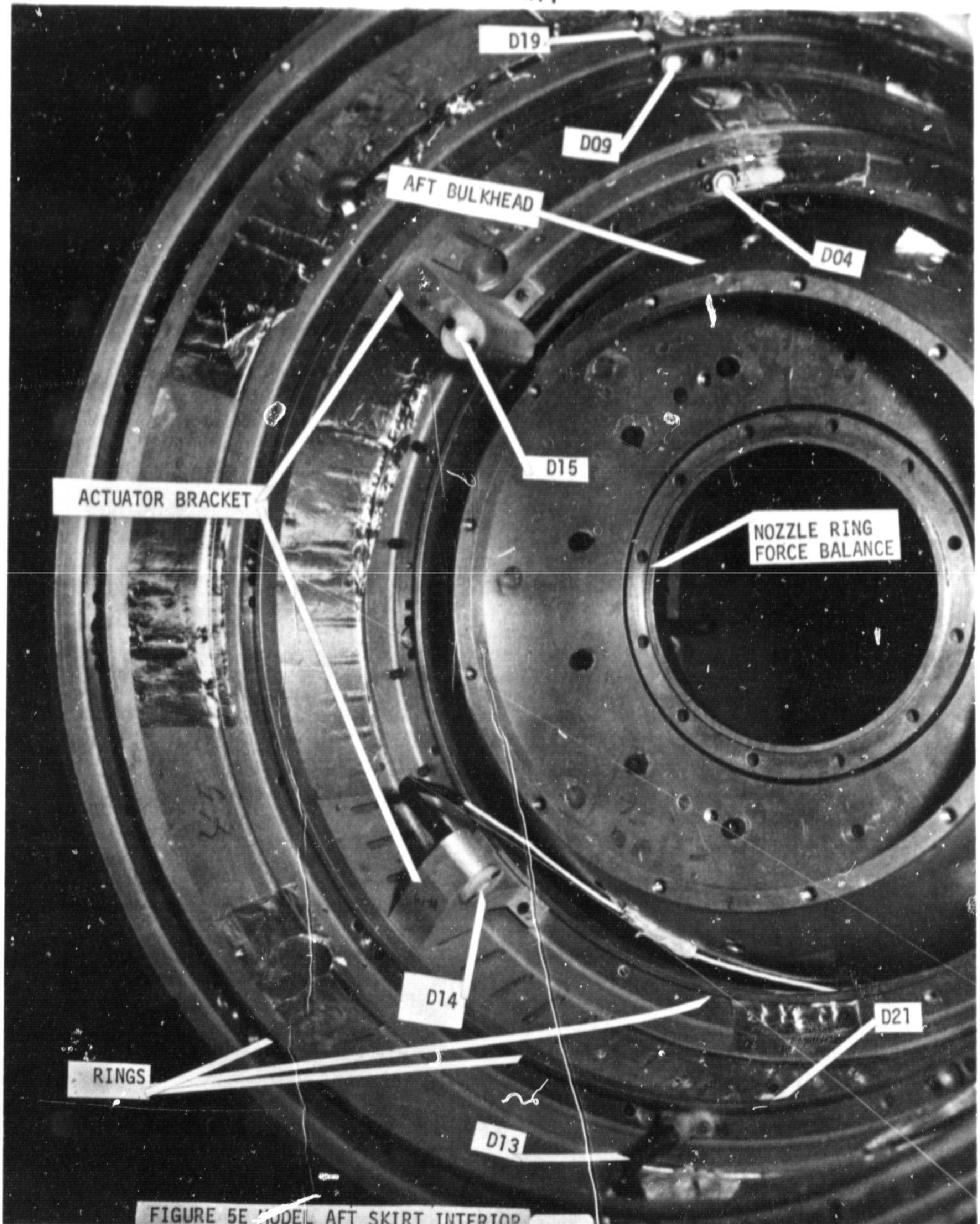

FIGURE 5E MODEL AFT SKIRT INTERIOR

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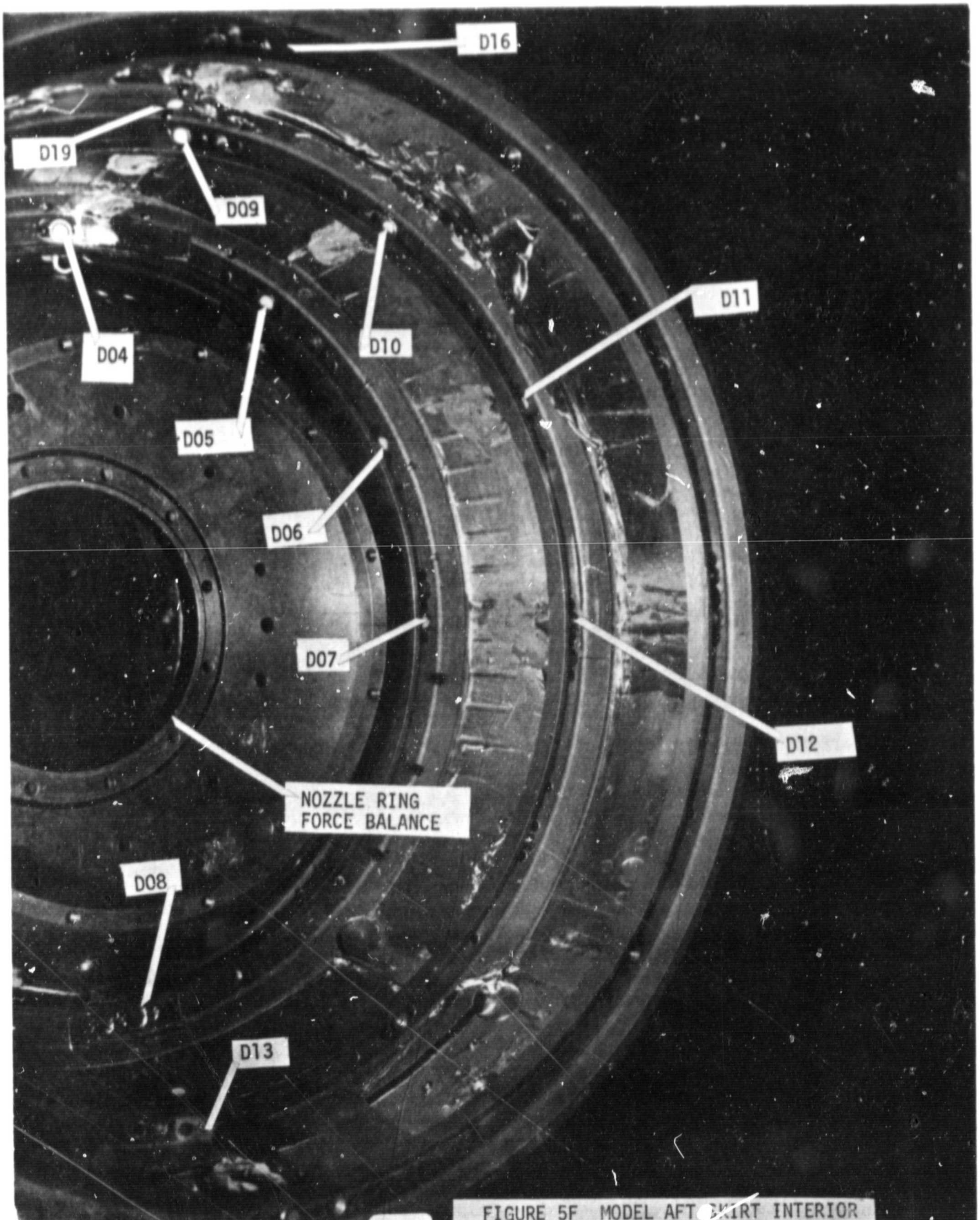

FIGURE 5F MODEL AFT SKIRT INTERIOR

The model instruments were water proofed with a combination of scotch cast epoxy resin, RTV and silicone grease. To protect the pressure transducers from thermal shocks, the diaphrams were recessed approximately 1/16 of an inch below the model skin and covered with RTV.

All instruments were bench calibrated prior to installation in the model and were check calibrated through the model instrument system after all wiring had been completed. In addition, hydrostatic pressure transducer calibrations were performed during the test by allowing the model to sink below the water surface.

Transducer signals were transmitted from the model through an instrument cable that attached to model top centerline near the C.G. This cable was approximately 1.5 inches in diameter, 100 feet long. The instrument cable was made up of 5-20 conductor shielded pairs of 20 gage teflon insulated wire and a power cable. All instruments used a 5 volt common power which was connected to the individual transducers through a terminal strip located inside the model.

Pressure, acceleration and strain gage outputs from the instrument cable were fed through appropriate couplers or signal conditioners/amplifiers to two, 14 channel, FM tape recorders. Data was recorded at 30 IPS, wide band, (108 KHZ center frequency). IR16"B" time was recorded on channel 14 of each recorder.

SECTION IV - TEST FACILITY

This test was conducted in the Hydroballistics Tank at the U.S. Naval Surface Weapons Center, White Oak, Maryland. This tank is 35 feet wide, 100 feet long and 75 feet deep with a water depth variable from zero to 65 feet. To preserve water clarity the tank is lined with stainless steel and the water is continuously filtered. A two foot thick reinforced concrete honeycomb structure surrounds the tank and is designed to permit reduction of air pressure above the water for model scaling. Steam ejectors located on the building roof are used to evacuate the tank for pressure scaled tests.

Depending upon water level, access to the tank is obtained either through a door in the bottom of the tank, two personnel hatches in the ceiling, or by removing one of the nine 3-foot diameter gun ports located in the north wall and ceiling. Work inside the tank is performed from either a raft, a catwalk, or a movable bridge 6.5 feet high by 10 feet wide which spans the 35 foot width of the tank at the 61 foot elevation. For photographic or visual observations 16 inch diameter portholes are located 11 feet on center in the tank floor, walls, and ceiling. Figures 6A and 6B are illustrations of the hydroballistics tank.

HYDROBALLISTICS TANK

The Hydroballistics Tank provides experimental data on water entry, simulating the performance of any missiles which enter the water after supersonic flight. Studies can also be made of underwater launching and water exit and of powered, maneuverable, scaled models of submarines and torpedoes. The massive, reinforced concrete honeycomb around the tank is designed to permit reduction of air pressure above the water for cavitation scaling. Two hundred 16-inch diameter glass windows in the tank walls permit photography and visual observations. Guns launch models into the tank through 3-foot ports in the end, top, and bottom. The stainless steel tank lining preserves the clarity of the extensively-filtered one and three-quarter million gallons of water.

The 4-inch powder guns use a saboting technique which prevents powder gases and contaminants from entering the tank. A fire-control system permits the automatic sequencing of 30 timing operations to actuate instrumentation during a launching.

The hydrodynamicist or engineer may participate in basic and applied research concerning water entry and exit phenomena, utilizing NOL's multimillion dollar hydroballistics facility. The Laboratory is interested in such things as the forces and moments that missiles experience when entering the water at high velocity; the motion of missiles during water entry and while riding in the water-entry cavity; and acoustic studies of the signals generated during cavity collapse.

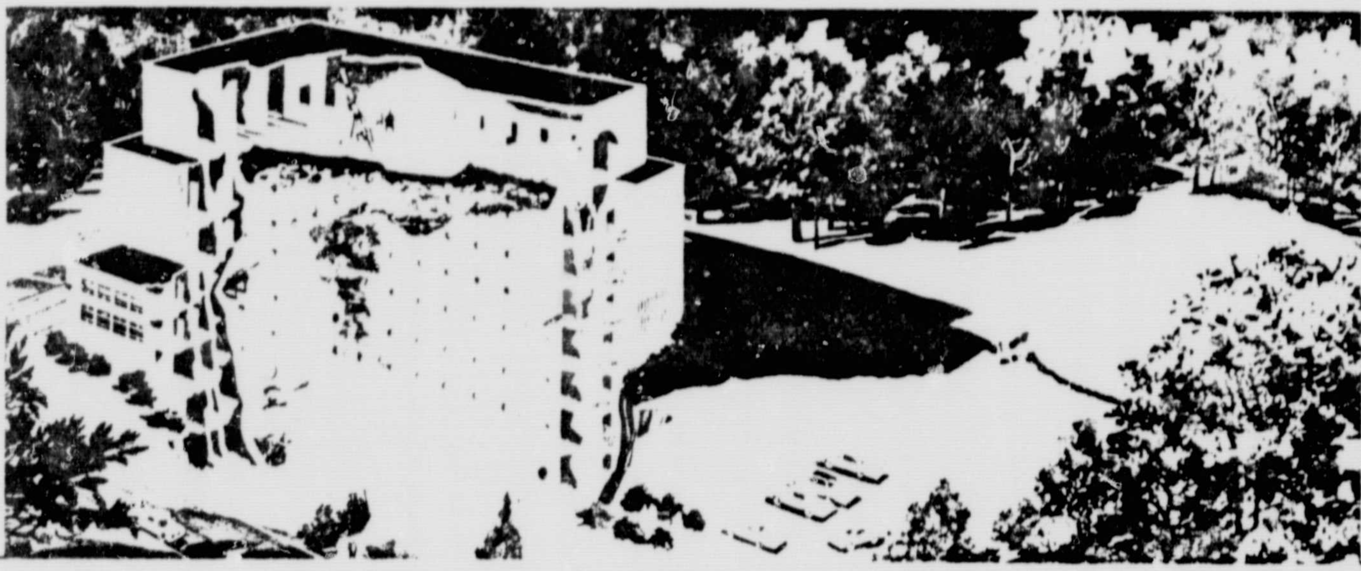

FIGURE 6A. SECTIONAL VIEW OF HYDROBALLISTICS TANK

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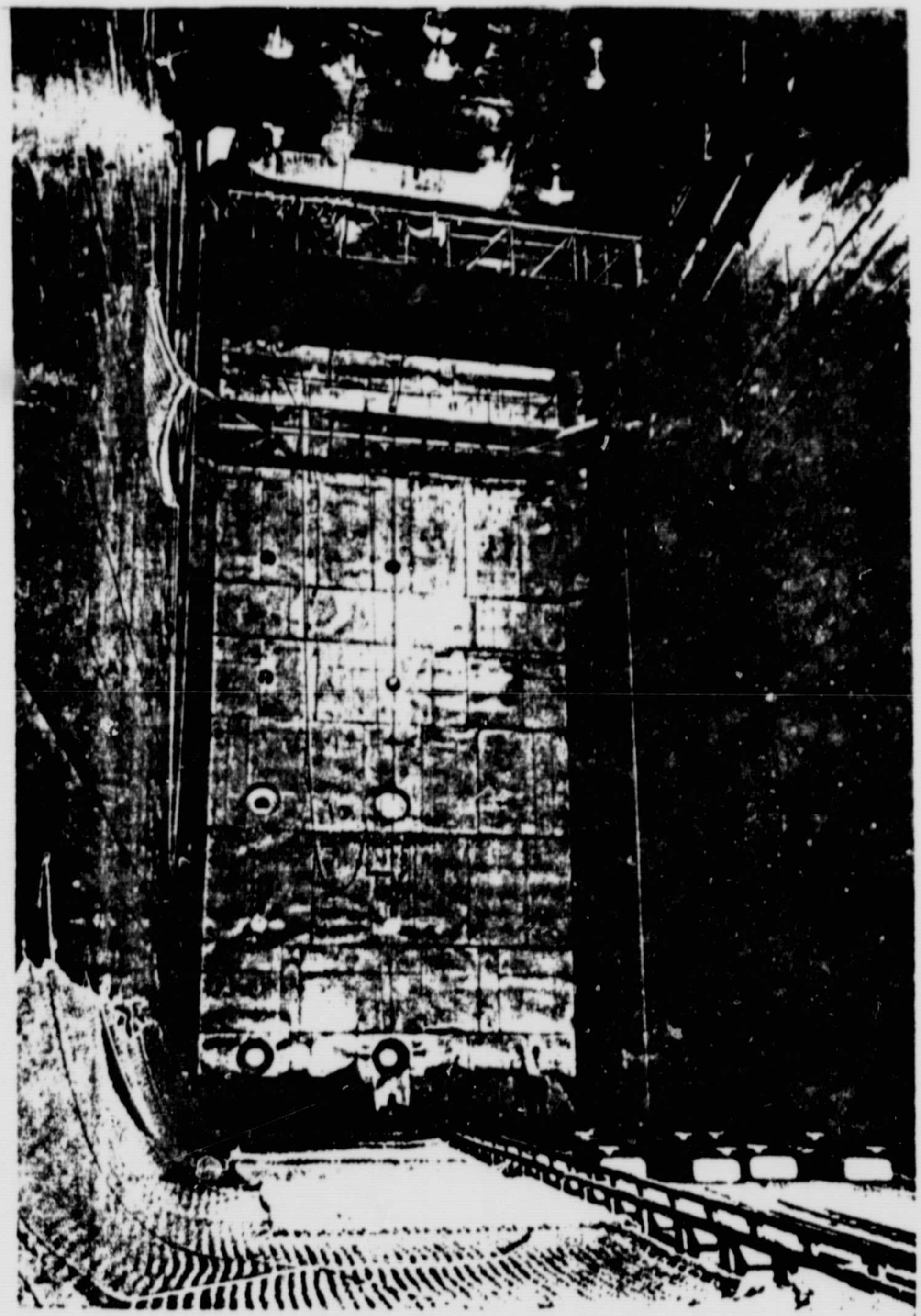
Operating Characteristics

Tank length	100 feet
Tank width	35 feet
Tank height	75 feet
Water depth	65 feet
Launcher	Powder gas guns (compressed gas launcher for low velocities)
Projectile	3 inch, 6 pounds maximum
Velocity	3000 feet per second
Firing angle	Vertical to horizontal
Instrumentation	Fire control unit to synchronize launcher-camera operation, multi-channel tape recorder system to monitor telemetry signals, optical whip recorder to measure angular motion of water entry, high speed 16 mm and 35 mm cameras to record the entire model trajectory.



Inside view of the Hydroballistics Tank

FIGURE 6B. INSIDE VIEW OF HYDROBALLISTICS TANK

SECTION V - PHOTOGRAPHIC INSTRUMENTATION

Photographic coverage for this test was provided by two high speed 16mm data cameras, and one 16mm documentary camera. The data cameras were set up in and perpendicular to the model pitch and yaw planes in port holes 504 and 524 for tests 1 through 50, then moved to port holes 404 and 422 for tests 51 through 59. The cameras were sighted so that the lens centerline was at the water surface to permit split water line viewing above and below water with each camera. Both cameras ran at approximately 250 FPS, used a 1/650 sec. exposure time, had a 60 CPS timing signal and were force processed one stop.

A documentary camera was located in port hole 624 which was 41 feet in front of and 11 feet above the model impact point.

The tank lighting consisted of 7 banks of 12 bulbs each below the water and 2 banks of 12 bulbs each and 4 light bars with 2 bulbs each above the water line. All bulbs were 650 watt. A blue vinyl back drop 25 ft. wide by 20 feet long was suspended from the bridge to improve tank lighting. The west wall of the tank had been previously covered with white vinyl.

SECTION VI - TEST PROGRAM

Water impact tests using a 12.5 inch diameter scale model of the Space Shuttle SRB were conducted at the U.S. Naval Surface Weapons Center, White Oak, Maryland, from AUgust 9, 1982 through September 3, 1982. These tests were conducted in accordance with Marshall Space Flight Center document "Test Requirements for the SRB 8.56% Scale Model Water Impact Test Program. (Reference 1)

During the test program a total of 59 drops were made. 58 drops were made at a scaled atmospheric pressure of 1.26 psia and 1 drop was made without pressure scaling at P_a = 14.7 psia.

The model configuration was varied as noted in the Test Program (Table III) to the following:

CONFIGURATIONS:

I Baseline - TVC Pod on lee side, actuators @ 225^0 and 315^0. Figure 3C.

II Baseline with 5^0 canted nozzle. Figure 3C.

This test program was conducted at model scale impact velocities simulating the full scale vertical velocities of 75, 88 and 110 ft/sec. and horizontal drift velocities of 0, 15, 30, and 45 ft/sec. at impact angles of 0, $\pm 5^0$, and $\pm 10^0$. Table II lists programmed model impact conditions by order of drop number and Table III lists the drop numbers as a function of model impact condition. Actual test conditions achieved are defined in Table IV as measured by the 250 FPS photographic data.

The model test velocities were Froude scale values of full scale as shown below:

DROP TEST VELOCITIES

VERTICAL VELOCITIES FPS		HORIZONTAL VELOCITIES FPS	
FULL SCALE	MODEL SCALE	FULL SCALE	MODEL SCALE
-	-	0	0
75	21.94	15	4.4
88	25.75	30	8.8
110	32.2	45	13.2

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TABLE II TEST PROGRAM
(MODEL SCALE VALUES)

CONF. NO.	TEST NUMBER	VERTICAL VELOCITY FT/SEC	HORIZONTAL VELOCITY FT/SEC	IMPACT ANGLE - θ DEGREES	ROLL ANGLE - ∅ DEGREES	TEST PRESSURE mm.HG.
I	1	25.75	0	0	0	760
	2	25.75	0	0	0	65
	3	25.75	8.8	0	0	65
	4	23.45	8.8	-5	0	65
	5	25.75	8.8	+5	0	65
	6	25.75	8.8	+10	0	65
	7	25.75	13.2	0	0	65
	8	25.75	8.8	0	180	65
	9	25.75	8.8	+5	180	65
	10	25.75	8.8	-5	180	65
	11	25.75	8.8	-10	180	65
	12	25.75	13.2	0	180	65
	13	25.75	13.2	+10	0	65
	14	25.75	0	-5	0	65
	15	25.75	0	+5	0	65
	16	25.75	8.8	+5	0	65
	17	25.75	8.8	+10	0	65
	18	25.75	13.2	0	0	65
	19	25.75	13.2	+5	0	65
	20	25.75	4.4	0	0	65
	21	25.75	8.8	+5	0	65
II	22	25.75	8.8	0	0	65
	23	25.75	8.8	0	0	65

TABLE II TEST PROGRAM
(MODEL SCALE VALUES)

CONF. NO.	TEST NUMBER	VERTICAL VELOCITY FT/SEC	HORIZONTAL VELOCITY FT/SEC	IMPACT ANGLE - θ DEGREES	ROLL ANGLE - Ø DEGREES	TEST PRESSURE mm.HG.
	24	25.75	8.8	+10	0	65
	25	25.75	8.8	-10	0	65
	26	25.75	4.4	0.	0	65
	27	25.75	0	0	0	65
	28	25.75	0	-5	0	65
	29	25.75	0	-10	0	65
	30	21.94	8.8	0	0	65
	31	21.94	0	0	0	65
	32	21.94	8.8	0	180	65
	33	21.94	8.8	0	180	65
	34	21.94	8.8	+5	0	65
II	35	21.94	0	-5	0	65
	36	21.94	0	-0	0	65
	37	25.75	0	-10	0	65
	38	21.94	8.8	+5	0	65
	39	21.94	8.8	+5	180	65
	40	21.94	8.8	-5	0	65
	41	21.94	13.2	0	0	65
	42	21.94	13.2	0	0	65
	43	21.94	13.2	0	180	65
	44	21.94	13.2	+5	0	65
	45	21.94	13.2	+5	180	65
	46	21.94	13.2	+10	0	65

TABLE II TEST PROGRAM
(MODEL SCALE VALUES)

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CONF. NO.	TEST NUMBER	VERTICAL VELOCITY FT/SEC	HORIZONTAL VELOCITY FT/SEC	IMPACT ANGLE - θ DEGREES	ROLL ANGLE - Ø DEGREES	TEST PRESSURE mm.HG.
II	47	21.94	13.2	+10	180	65
	48	21.94	0	+5	0	65
	49	21.94	0	+10	0	65
	50	25.75	0	+10	0	65
	51	32.2	0	0	0	65
	52	32.2	0	-5	0	65
	53	32.2	0	-10	0	65
	54	32.2	8.8	0	0	65
	55	32.2	4.4	0	0	65
	56	32.2	8.8	+5	0	65
	57	32.2	0	+5	0	65
	58	32.0	0	+10	0	65
	59	32.0	13.2	+5	0	65

CONFIGURATION LEGEND

I: BASELINE - TVC POD ON LEE SIDE, ACTUATORS @ 225° AND 315° FIGURE

II: BASELINE WITH 5° CANTED NOZZLE FIGURE

TABLE III

TEST NUMBER MATRIX

CONF NO.	FULL SCALE VERTICAL VELOCITY	FULL SCALE HORIZONTAL VELOCITY	MILLIMETERS MERCURY P_∞	ROLL ANGLE ϕ	IMPACT ANGLE (θ DEGREE) TEST NUMBER				
					-10	-5	0	5	10
I	88	0	760	0	–	–	01	–	–
	88	0	65	0	–	14	02	15	50
		15	65	0	–	–	20	–	–
		30	65	0	–	04	03	05,16,21	06,17
		45	65	0	–	–	07,18	19	13
	88	0	65	180	–	–	–	–	–
		15	65	180	–	–	–	–	–
		30	65	180	11	10	08	09	–
		45	65	180	–	–	12	–	–
II	75	0	65	0	36	35	31	48	49
		15	65	0	–	–	–	–	–
		30	65	0	38	40	30	34	–
		45	65	0	–	–	41,42	44	46
	75	0	65	180	–	–	–	–	–
		15	65	180	–	–	–	–	–
		30	65	180	–	–	32,33	39	–
		45	65	180	–	–	43	45	47

TABLE III
TEST NUMBER MATRIX

CONF. NO.	FULL SCALE VERTICAL VELOCITY	FULL SCALE HORIZONTAL VELOCITY	MILLIMETERS MERCURY P_∞	ROLL ANGLE ϕ	IMPACT ANGLE (θ DEGREE) TEST NUMBER				
					-10	-5	0	5	10
II	88	0	65	0	29,37	28	27	–	–
		15	65	0	–	–	26	–	–
		30	65	0	25	–	22	–	24
		45	65	0	–	–	23	–	–
	110	0	65	0	53	52	51	57	58
		15	65	0	–	–	55	–	–
		30	65	0	–	–	54	56	–
		45	65	0	–	–	59	–	–

LEGEND: CONFIGURATION I BASELINE TVC POD ON LEE SIDE, ACTUATORS @ 225° AND 315° FIGURE

II BASELINE WITH 5° CANTED NOZZLE FIGURE

TABLE IV PHOTOGRAPHIC DATA

TEST NUMBER	CONFIGURATION NUMBER	VERTICAL VELOCITY FT/SEC		HORIZONTAL VELOCITY FT/SEC		IMPACT ANGLE DEGREES		ROLL ANGLE DEGREES		TEST PRESSURE mm.Hg.
		NOMINAL	MEASURED	NOMINAL	MEASURED	NOMINAL	MEASURED	NOMINAL	MEASURED	
1		25.75	27.9	0	0	0	0	0	0	760
2		25.75	-	0	0	0	-	0	-	65
3		25.75	25.2	8.8	9.8	0	-1.5	0	0	
4		23.45	25.2	8.8	9.8	-5	-4.5	0	-25.2	
5		25.75	25.2	8.8	9.8	+5	+1	0	-40.2	
6		25.75	22.7	8.8	10.4	+10	+4.5	0	-66.2	
7		25.75	22.4	13.2	13.8	0	-2.0	0	-42.2	
8		25.75	22.7	8.8	10.4	0	-1.5	180	+30.5	
9		25.75	23.1	8.8	10.4	+5	+5.5	180	0	
10		25.75	24.4	8.8	9.0	-5	-5.5	180	0	
11	I	25.75	23.7	8.8	9.3	-10	-12.5	180	0	
12		25.75	24.6	13.2	14.0	0	0	180	0	
13		25.75	24.3	13.2	15.0	+10	+10.0	0	0	
14		25.75	24.1	0	0	-5	-6.5	0	0	
15		25.75	25.7	0	0	+5	+6.6	0	7.3	
16		25.75	24.3	8.8	10.6	+5	+2.5	0	-25.6	
17		25.75	21.0	8.8	9.3	+10	+11.0	0	-22.7	
18		25.75	23.6	13.2	15.5	0	0	0	-2.8	
19		25.75	27.1	13.2	16.6	+5	+5.5	0	10.1	
20		25.75	24.8	4.4	18.0	0	0	0	9.6	
21		25.75	25.0	8.8	10.6	+5	+7.0	0	-33.9	
22		25.75	24.7	8.8	10.2	0	-5.0	0	-29.0	
23	II	25.75	24.7	8.8	15.8	0	-1.0	0	14.5	65

TABLE IV PHOTOGRAPHIC DATA

TEST NUMBER	CONFIGURATION NUMBER	VERTICAL VELOCITY FT/SEC NOMINAL	VERTICAL VELOCITY FT/SEC MEASURED	HORIZONTAL VELOCITY FT/SEC NOMINAL	HORIZONTAL VELOCITY FT/SEC MEASURED	IMPACT ANGLE DEGREES NOMINAL	IMPACT ANGLE DEGREES MEASURED	ROLL ANGLE DEGREES NOMINAL	ROLL ANGLE DEGREES MEASURED	TEST PRESSURE mm.Hg.
24		25.75	25.5	8.8	10.2	+10	10	0	-30	65
25		25.75	23.9	8.8	9.5	-10	-10	0	-4.8	
26		25.75	24.6	4.4	6.4	0	-1.0	0	3.9	
27		25.75	24.3	0	0	0	.5	0	7.8	
28		25.75	23.2	0	0	-5	-5.5	0	2.3	
29		25.75	23.6	0	0	-10	9.0	0	2.3	
30		21.94	21.8	8.8	10.7	0	1.0	0	0	
31		21.94	19.5	0	0	0	.5	0	6.3	
32		21.94	20.6	8.8	19.1	0	.5	180	22.4	
33		21.94	19.9	8.8	9.3	0	0	180	-30	
34	II	21.94	21.2	8.8	10.2	+5	3.5	0	-49	
35		21.94	20.1	0	0	-5	-6.0	0	0	
36		21.94	20.8	0	0	0	-10.5	0	0	
37		25.75	24.1	0	0	-10	-9.0	0	-13	
38		21.94	19.9	8.8	9.9	+5	5.0	0	+6	
39		21.94	19	8.8	8.8	+5	6.0	180	-38	
40		21.94	19.5	8.8	9.1	-5	-5.0	0	-6	
41		21.94	9.2	13.2	13.6	0	3.0	0	-6	
42		21.94	20.6	13.2	13.5	0	-.5	0	-10	
43		21.94	18.7	13.2	14.3	0	1.0	180	12	
44		21.94	20.1	13.2	14.3	+5	5.0	0	7	
45		21.94	20.1	13.2	13.5	+5	5.0	180	-4	
46		21.94	19.2	13.2	13.3	+10	9.5	0	0	65

TABLE IV PHOTOGRAPHIC DATA

TEST NUMBER	CONFIGURATION NUMBER	VERTICAL VELOCITY FT/SEC		HORIZONTAL VELOCITY FT/SEC		IMPACT ANGLE DEGREES		ROLL ANGLE DEGREES		TEST PRESSURE mm.Hg.
		NOMINAL	MEASURED	NOMINAL	MEASURED	NOMINAL	MEASURED	NOMINAL	MEASURED	
47		21.94	19.5	13.2	14.5	+10	9.5	180	TBD	65
48		21.94	20.4	0	0	+5	6.5	0		
49		21.94	19.3	0	0	+10	10.5	0		
50		25.75	23.7	0	0	+10	10.0	0		
51		32.2	TBD	0	TBD	0	TBD	0		
52		32.2		0		-5		0		
53	II	32.2		0		-10		0		
54		32.2		8.8		0		0		
55		32.2		4.4		0		0		
56		32.2		8.8		+5		0		
57		32.2		0		+5		0		
58		32.2		0		+10		0		
59		32.2		13.2		+5		0		65

SECTION VII - TEST OPERATIONS

The pressure scaled water impact test was conducted using the SRB model launcher (Figure 7) fabricated under the direction of Chrysler in 1974. For this test it was removed from storage at the NSWC, White Oak, Md., where it was refurbished, installed, and calibrated, by Chrysler personnel. The launcher's two major components are the horizontal support beam and the model carriage release dolley. The structures were fabricated of 1.5 inch square 6061 aluminum tubing with a combined weight of approximately 400 lbs. Installation and assembly of the SRB model launcher was accomplished in August 1982; it was attached to the movable bridge within the tank with (4) I-Beams. The tank water level was lowered to the 24-foot elevation and the gun port hatch adjacent to the loading dock was removed for access to the tank. The horizontal support beam, model carriage, I-beams, rails, work platforms, and dummy model were moved into the tank and placed on a raft. This raft was moved to center tank and tied below the bridge. The gun port hatch was replaced and tank pumps were started to raise the water for assembly of the launcher. This required approximately 8 hours.

Calibration and testing started August 11th and ended September 2nd after 59 test drops with varied vertical and horizontal velocities. Vertical velocities were varied by changing the height of the horizontal support beam. Horizontal velocities were varied by changing the travel of the model carriage. The carriage dolley was propelled (on rails) along the horizontal support beam through the release cam assembly, by means of a 426 lb. drop weight. The carriage dolley held

the model in a spring loaded clamp that opened when it contacted the release cam assembly. Figures 8 through 12. The clamp was also used for variation of the model impact angles. The release cam assembly, Figures 13 through 18, was attached to the horizontal support beam with 2-2" "C" clamps. Cam locations were pre-determined during calibration; horizontal velocities and a model drop "free fall window" were established. Calibration was accomplished using a dummy model for approximately 20 calibration drops. The drop weight was the only propelling force used for the launcher. The weight was shackled to a 3/8 inch wire rope 12 ft. long with a 1/2 inch round dog on the end.

The instrumented model was initially loaded into the launcher through a port hole (in the top of the test facility) directly into the model carriage dolley clamps, using an overhead crane, located outside and above the tank top. The carriage dolley clamp was positioned under the port hole near the end of the horizontal beam. Once the model was initially loaded inside the tank the port hole cover was replaced. Subsequent loadings were accomplished using the same over head crane but with a cable that was lowered thru a small hole in the port hole cover. After model loading the line was removed and a cover placed on the hold.

The model was held in the carriage dolley clamp by two launching lugs secured to the model sides, Figure 20. To insure correct angle and

tight fit (4) bolts on each clamp were used to snug the clamp around the lugs (Figure 11). When the model was secured in the dolley clamp, the dolley was then rolled along the horizontal beam a predetermined distance established for the desired horizontal velocity. Once the dolley was in the proper location the release cam assembly was "C" clamped to the horizontal beam at a predetermined calibration location. This release cam assembly was equipped with three circuits, including pencil leads on 2" centers. A knife type blade on the dolley was used to break the leads, and circuits, thus allowing the horizontal velocities to be calculated. Three velocities were calculated; (1) prior to release, (2) at release, (3) after release. This circuitry was checked before closing the tank. With the cam assembly in place, the excess instrument cable was then hung on a drop arm located on the underside of dolley. This removed all weight of the cable from the model. (Figure 7).

The next procedure was to load the drop weight. This was accomplished using a winch located on the underside of the tank top above the drop weight. The winch hook was lowered to pick up the drop weight, lifting it to allow the wire rope attached to the weight, (dog end) to be wrapped around and inserted into a hole in the spool, of the spool, chain drive sprocket, and brake assembly.

The spool, chain drive sprocket, and disc brake were mounted on a 1-inch shaft, Figures 21 through 24. The assembly was used to drive the dolley along the horizontal beam tracks thru a chain attached to the carriage dolley. The

disc brake part of this assembly was used to hold the loaded drop weight, release the weight, and assist in the stopping of the carriage dolley after model release. Once the wire rope was wrapped the correct numbers of turns and the dog installed in the spool, the weight was then lowered to hang from the spool by the wire rope, and held by the disc brake.

Two stop ropes were attached to the drop weight. One was used as a stop; to prevent the weight from falling to the bottom of the tank, the other was a backup. When the disc brake was released the weight pulled on the wire rope wrapped on the spool thus propelling the dolley along the horizontal beam through the release assembly, dropping the model into the water within the free fall window (Figure 31). A retrieval line secured to the top of the model was used to raise the model from the water after pressure drops, before venting of the tank. This was accomplished with a second winch located inside the tank and operating remotely from the data control area. (Figures 28 and 29).

Zero horizontal velocity test drops were accomplished without the use of the horizontal launcher. A solenoid release mechanism installed in the special porthole cover was used, Figures 25 through 27.

The model was hung with a wire rope attached to a ring that was dropped from a pin released by the solenoid. Angles and veloticities were varied by changing the length of the wire rope (model height) and the angle at which the model was held. A wood support (2x4) attached to the

movable bridge was used to hold the cable drop arm, Figure 30.

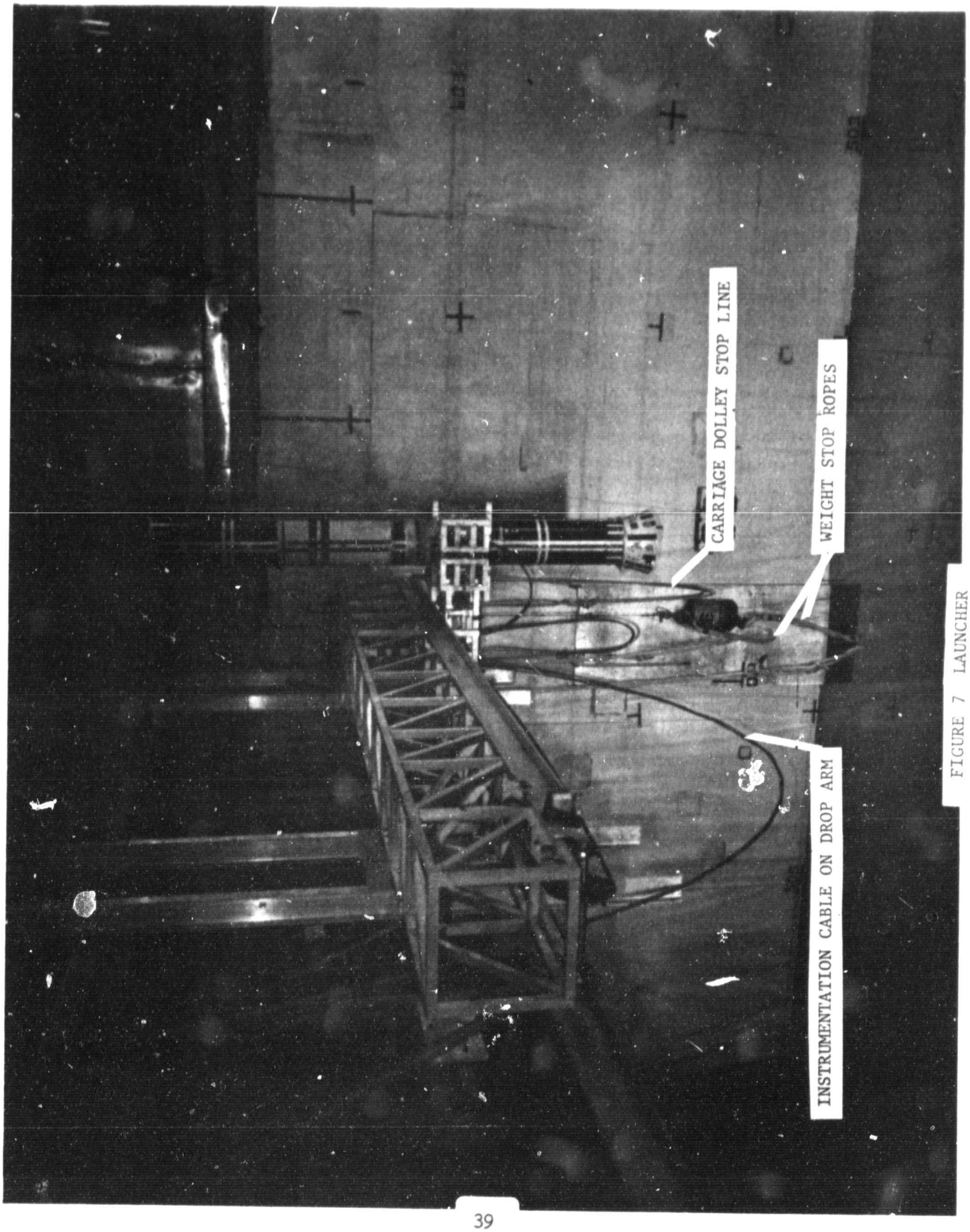

FIGURE 7 LAUNCHER

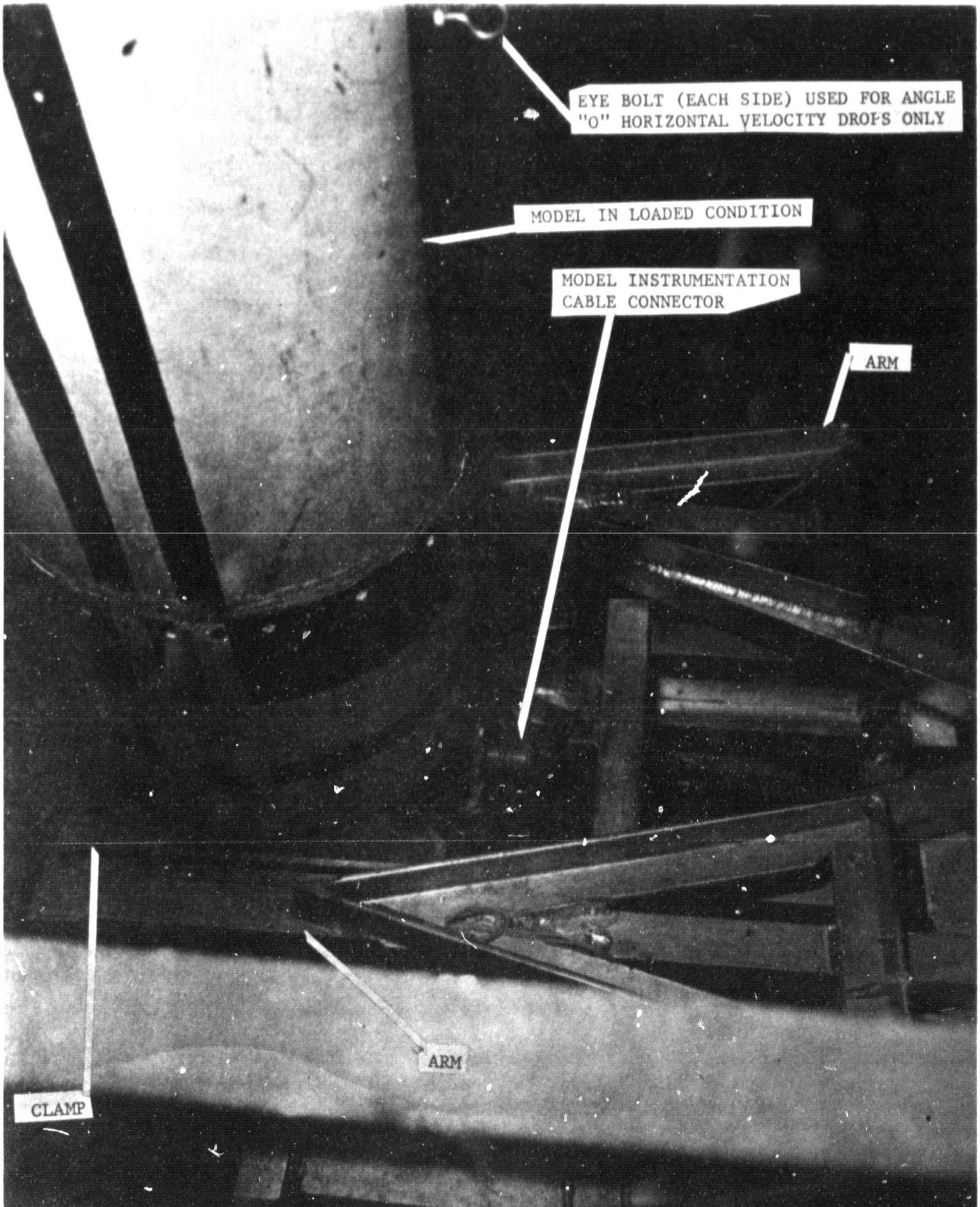

FIGURE 8 MODEL LOADED IN CARRIAGE DOLLEY CLAMP

FIGURE 9 CARRIAGE DOLLEY CLAMP

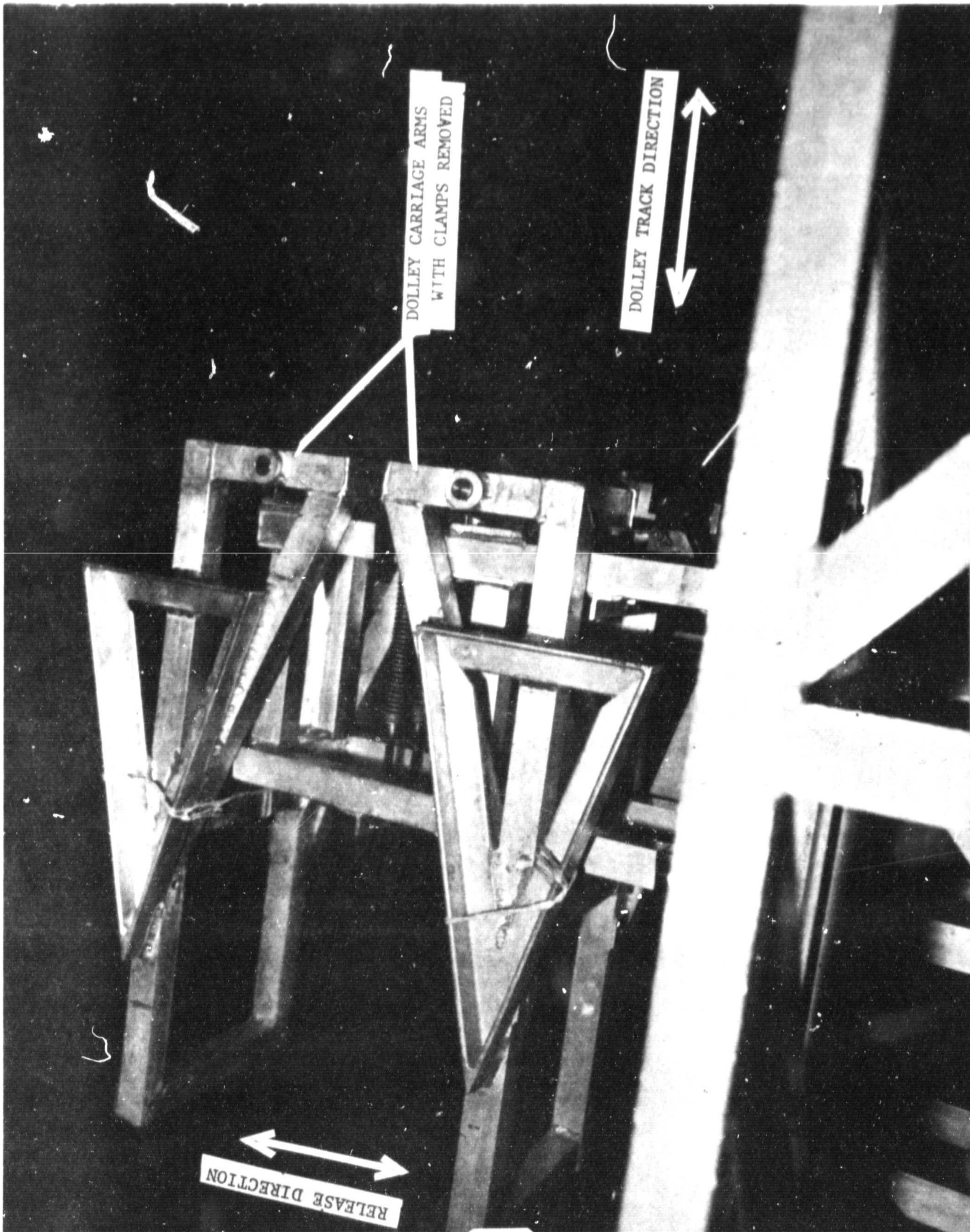

FIGURE 10 CARRIAGE DOLLEY CLAMP

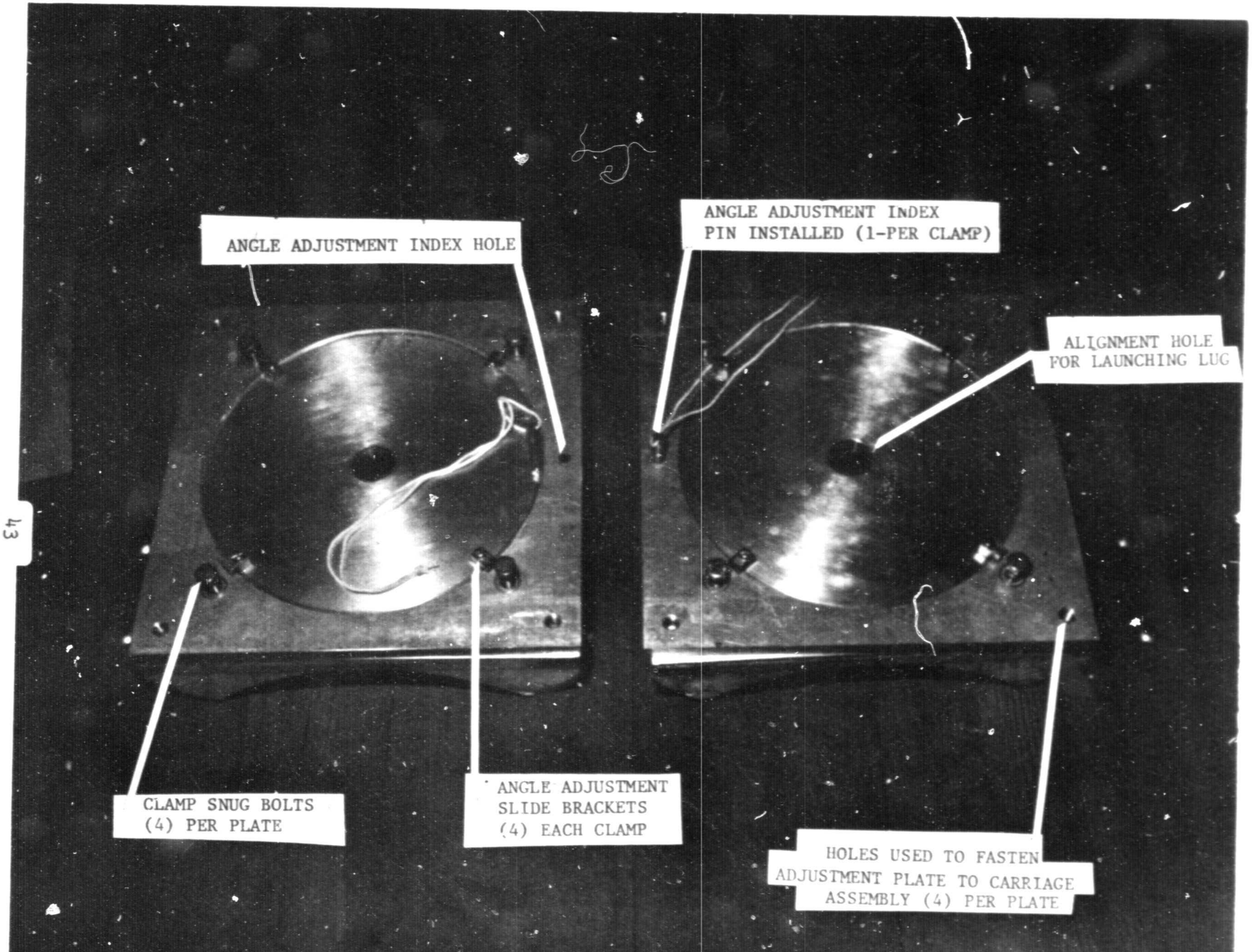

FIGURE 11 CLAMPS (ADJUSTMENT SIDE VIEW)

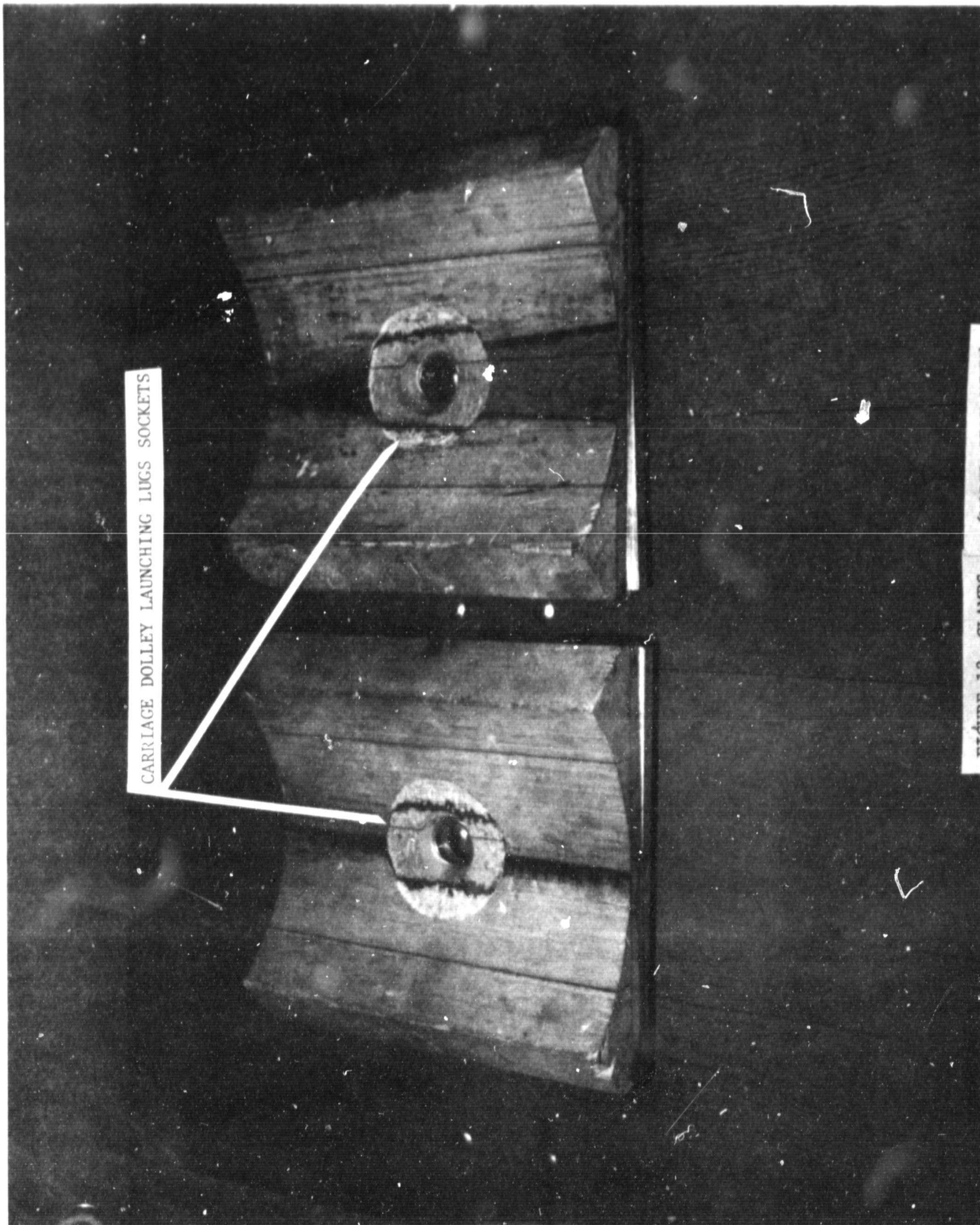

FIGURE 12 CLAMPS (MODEL SIDE VIEW)

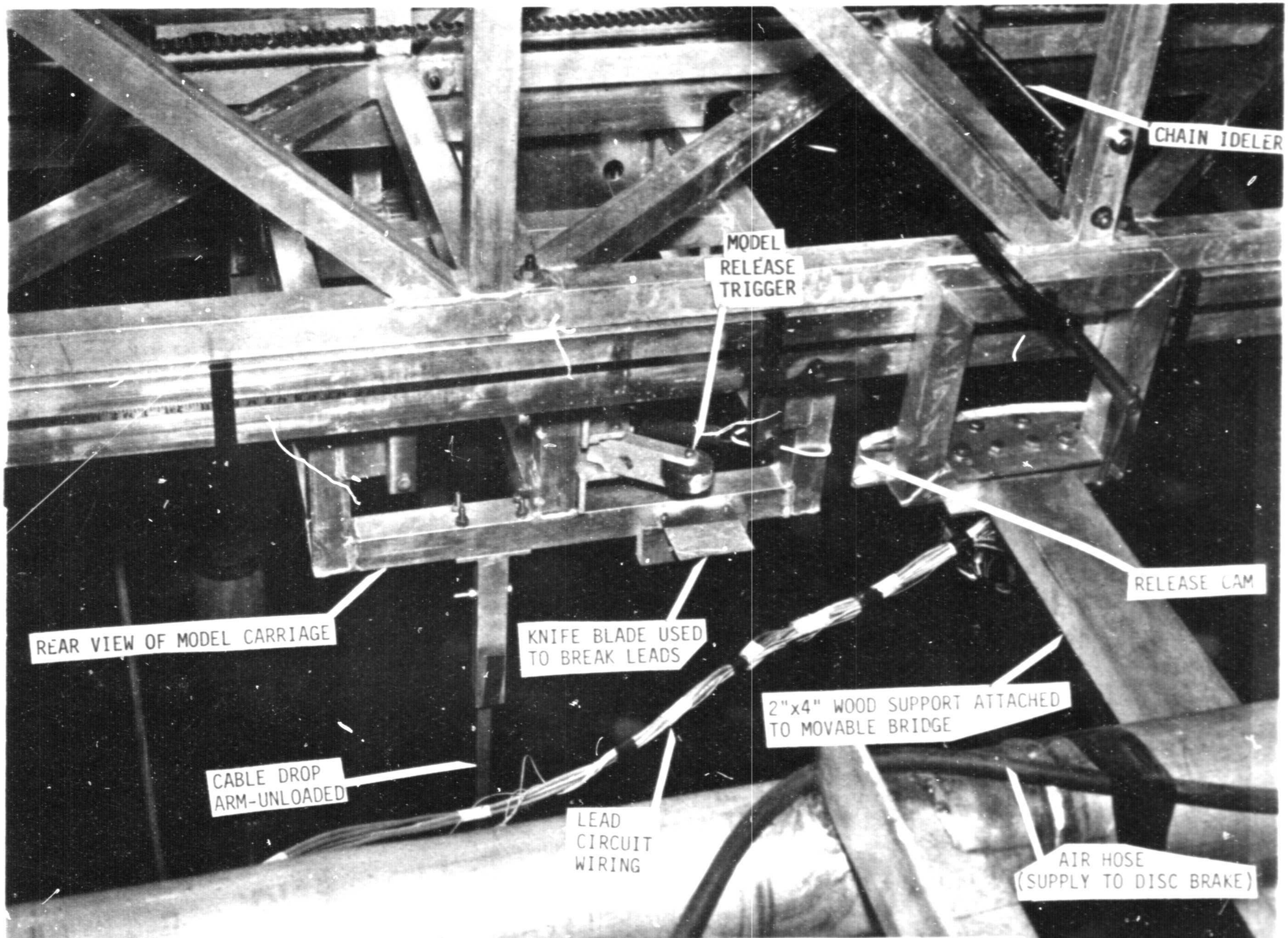

FIGURE 13 REAR VIEW OF HORIZONTAL SUPPORT ARM WITH RELEASE CAM IN PLACE

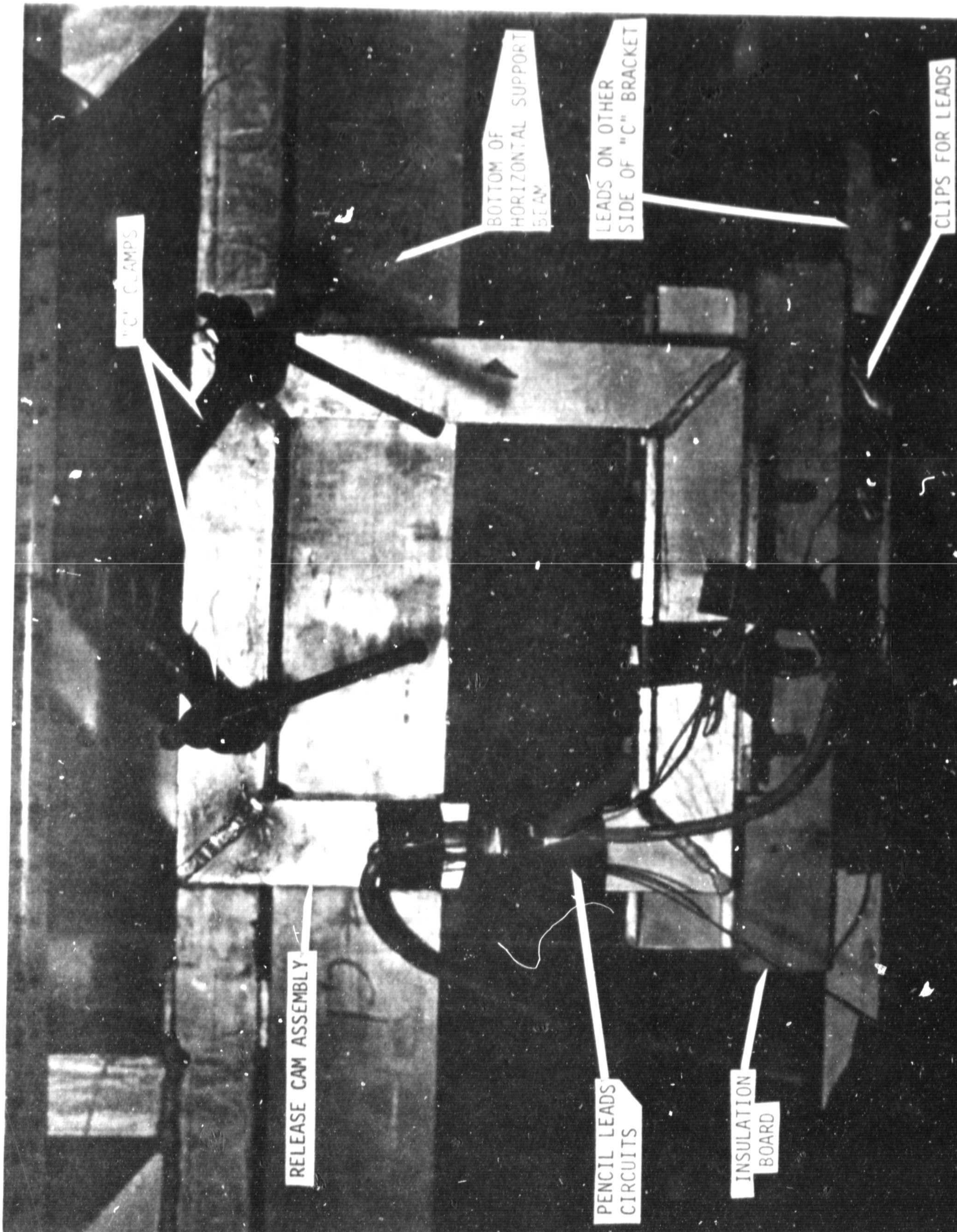

FIGURE 14 REAR VIEW OF RELEASE CAM ATTACHED TO HORIZONTAL SUPPORT BEAM
(AWAY FROM MODEL)

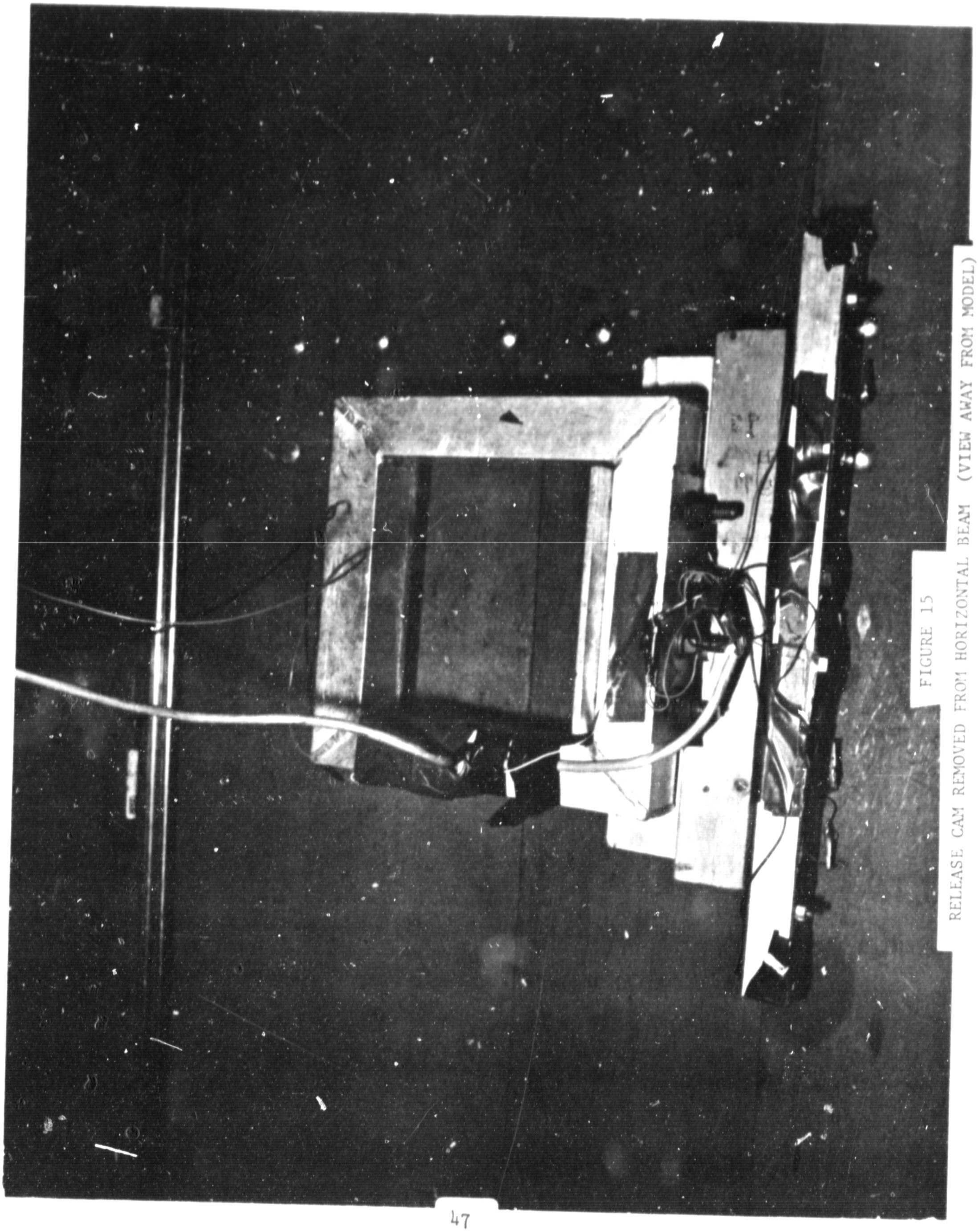

FIGURE 15

RELEASE CAM REMOVED FROM HORIZONTAL BEAM (VIEW AWAY FROM MODEL)

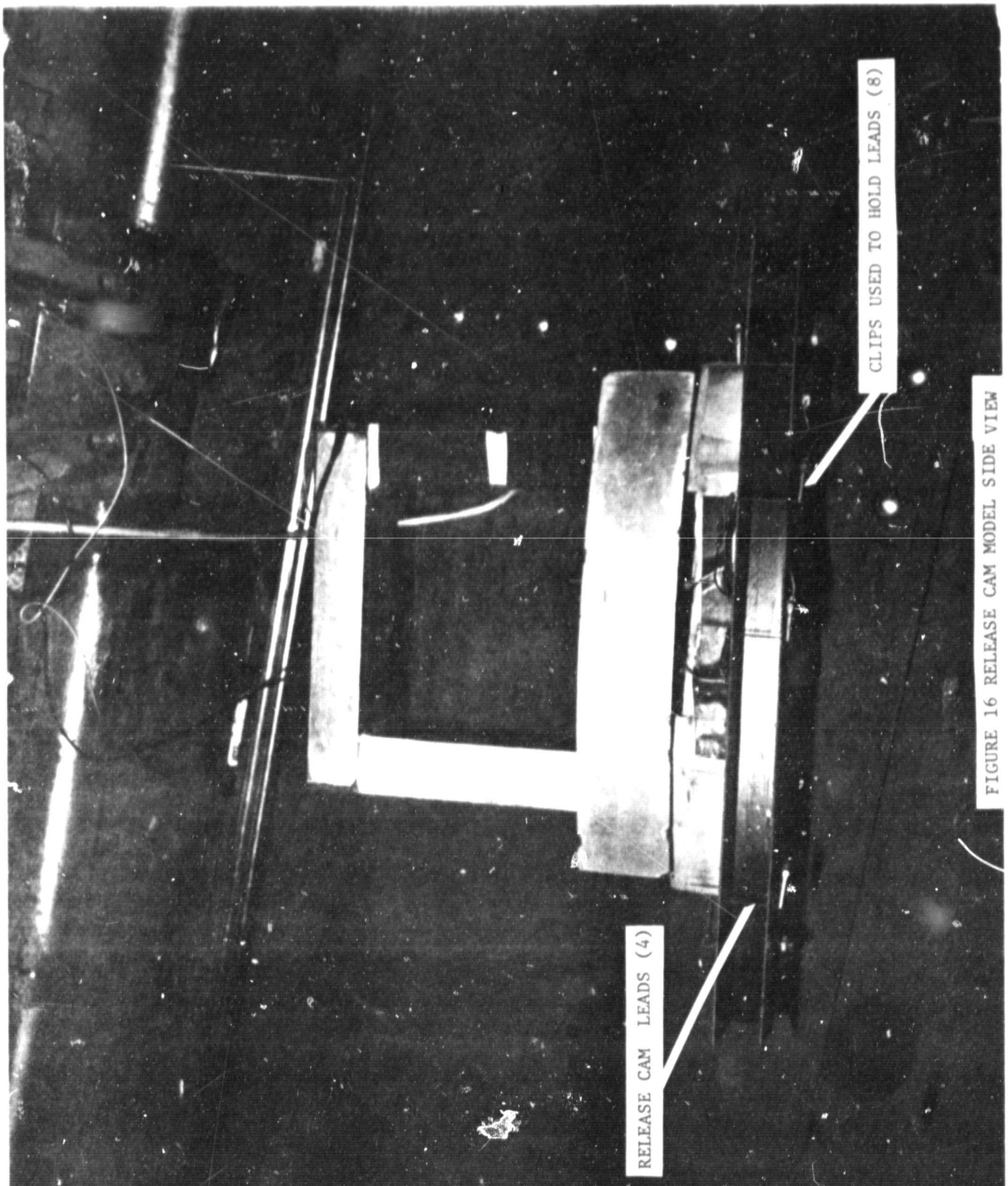

FIGURE 16 RELEASE CAM MODEL SIDE VIEW

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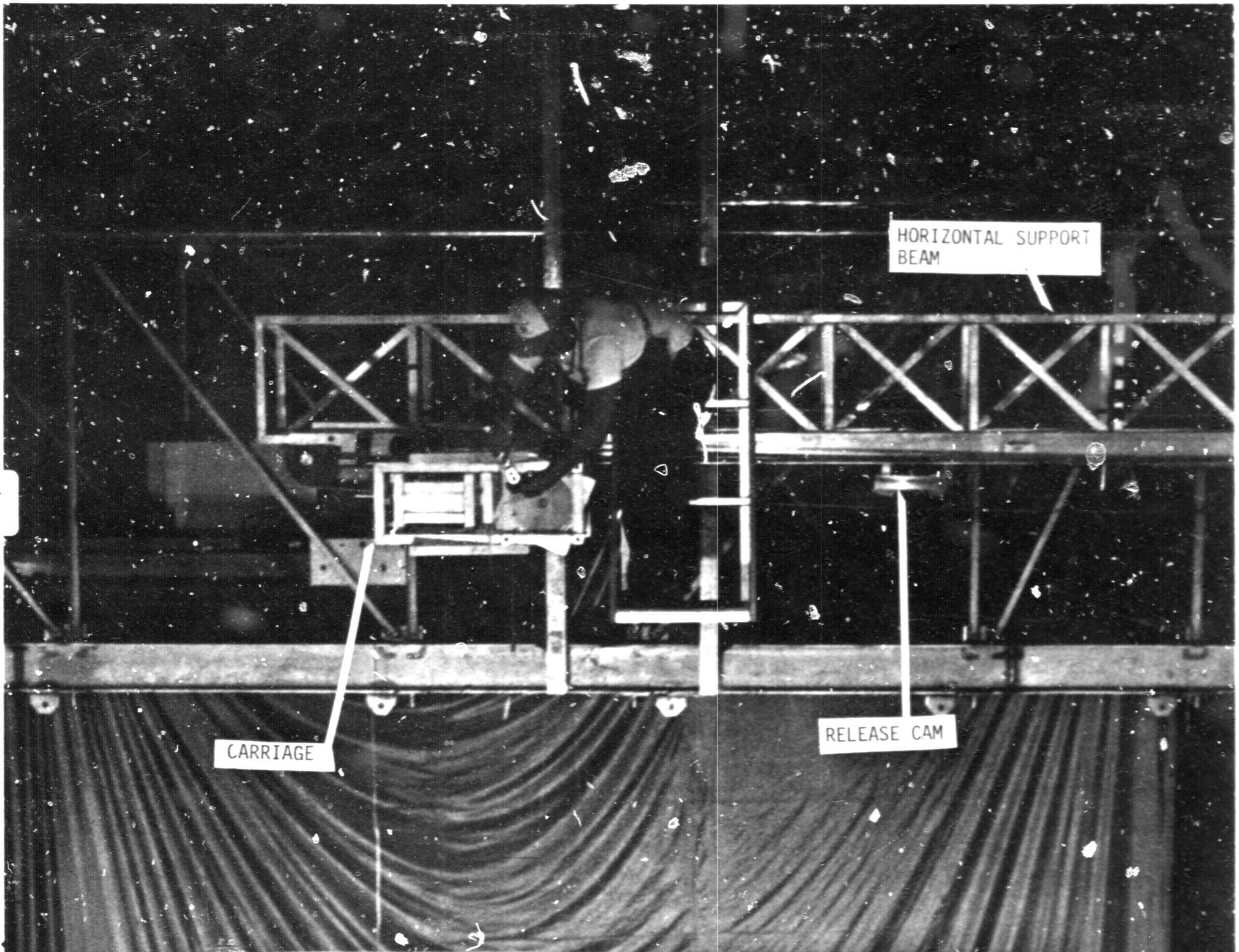

FIGURE 17 ADJUSTING DOLLEY CLAMP TO RECEIVE MODEL FOR ANGLE DROP TESTS

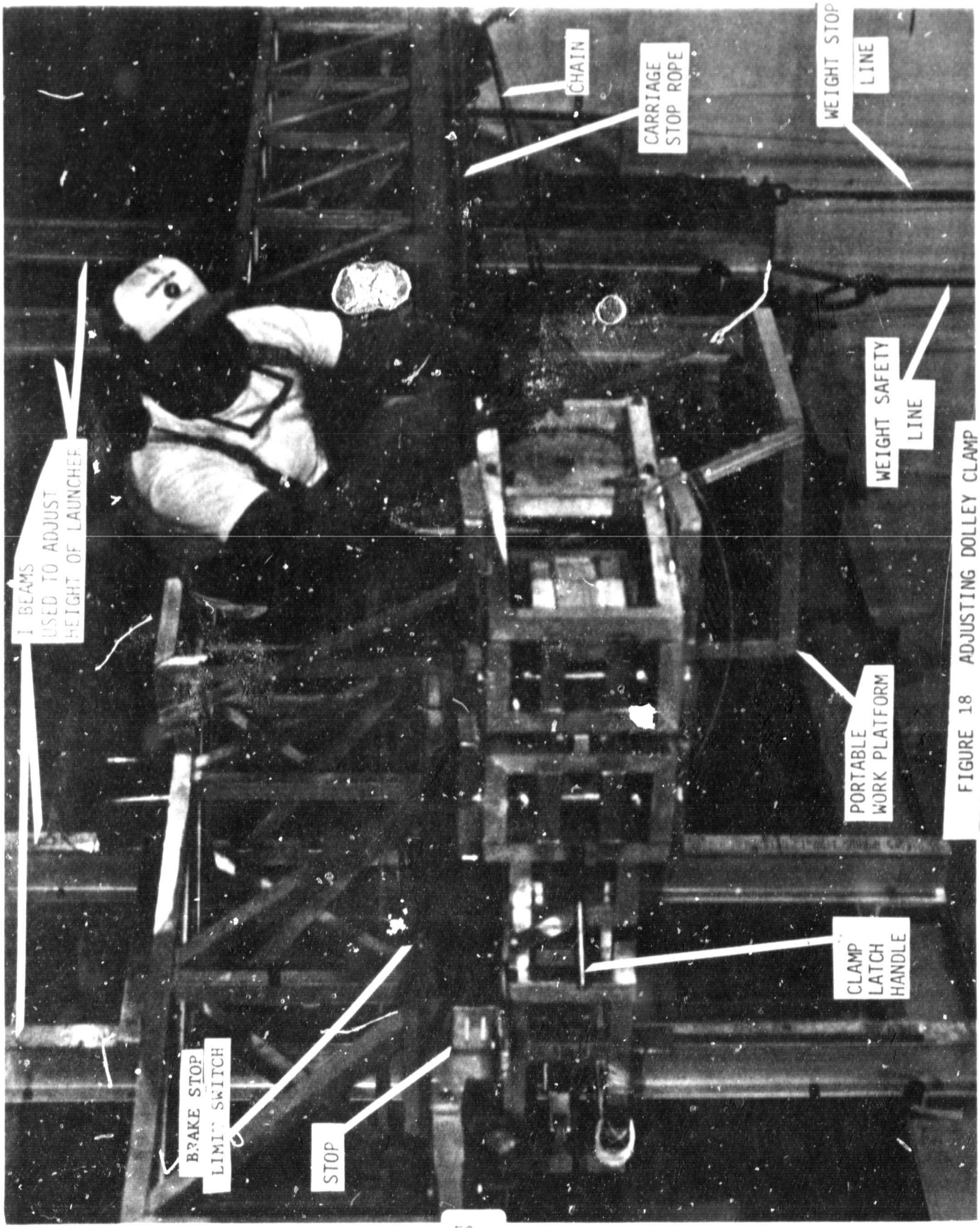

FIGURE 18 ADJUSTING DOLLEY CLAMP

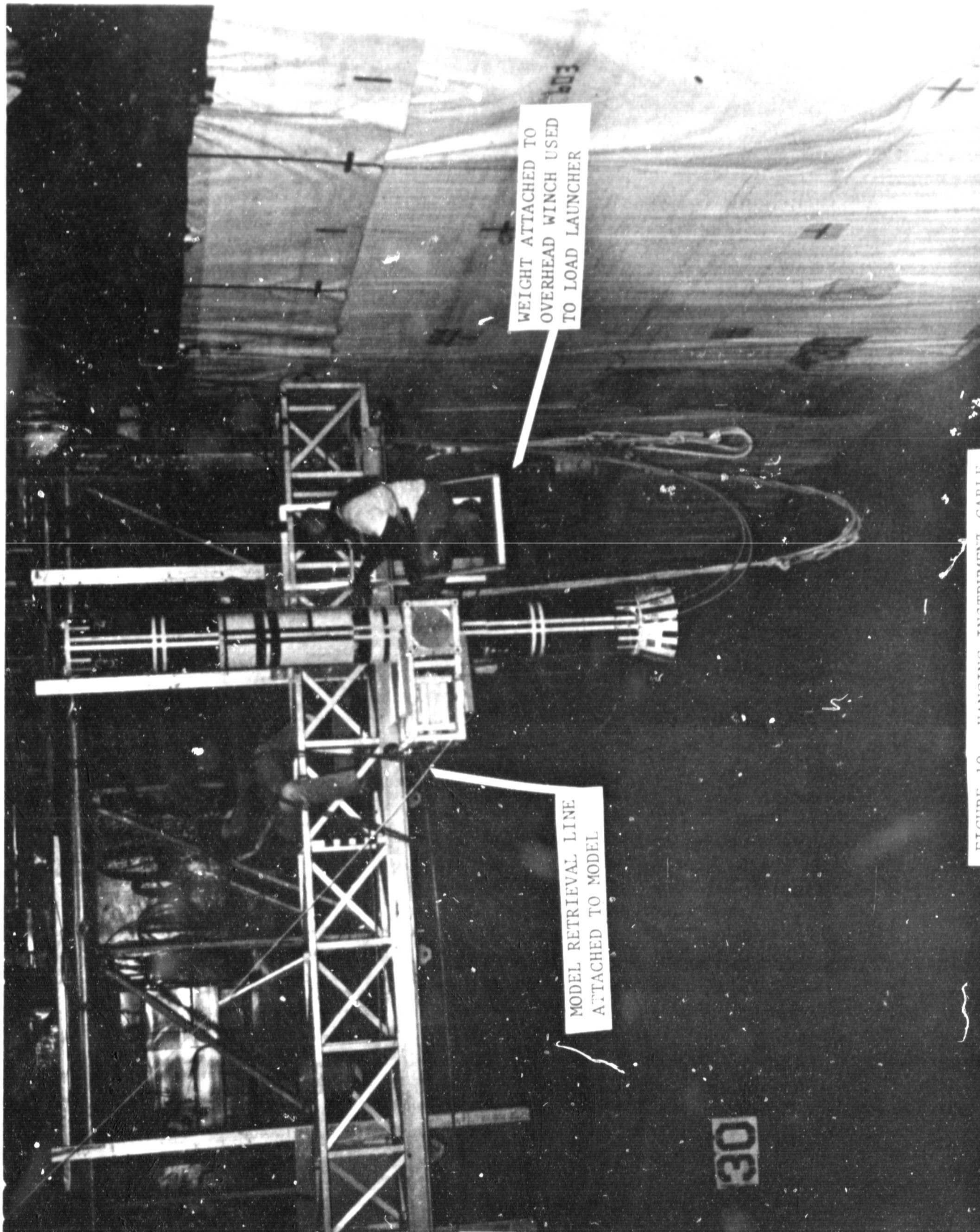

FIGURE 19 HANGING INSTRUMENT CABLE

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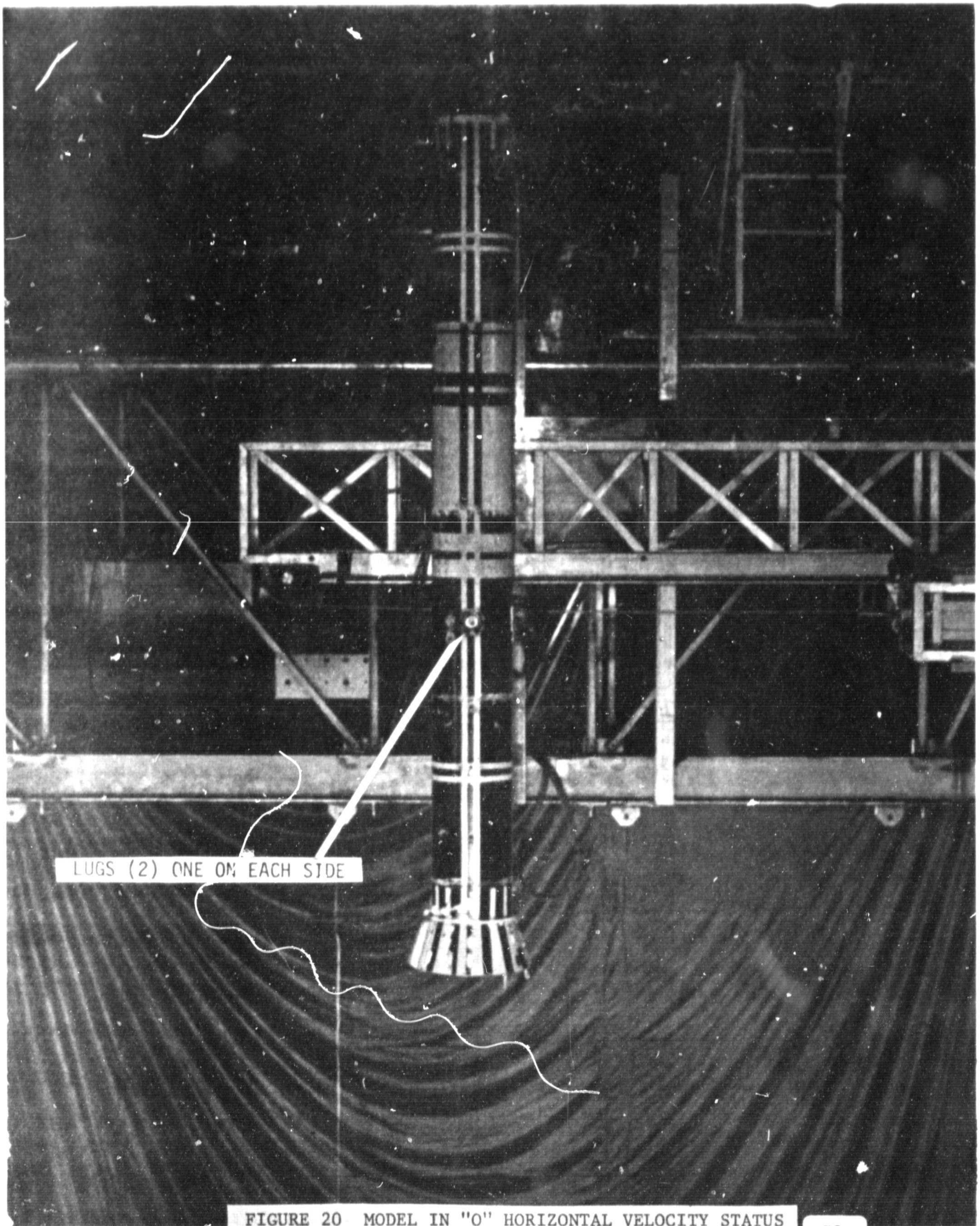

FIGURE 20 MODEL IN "O" HORIZONTAL VELOCITY STATUS

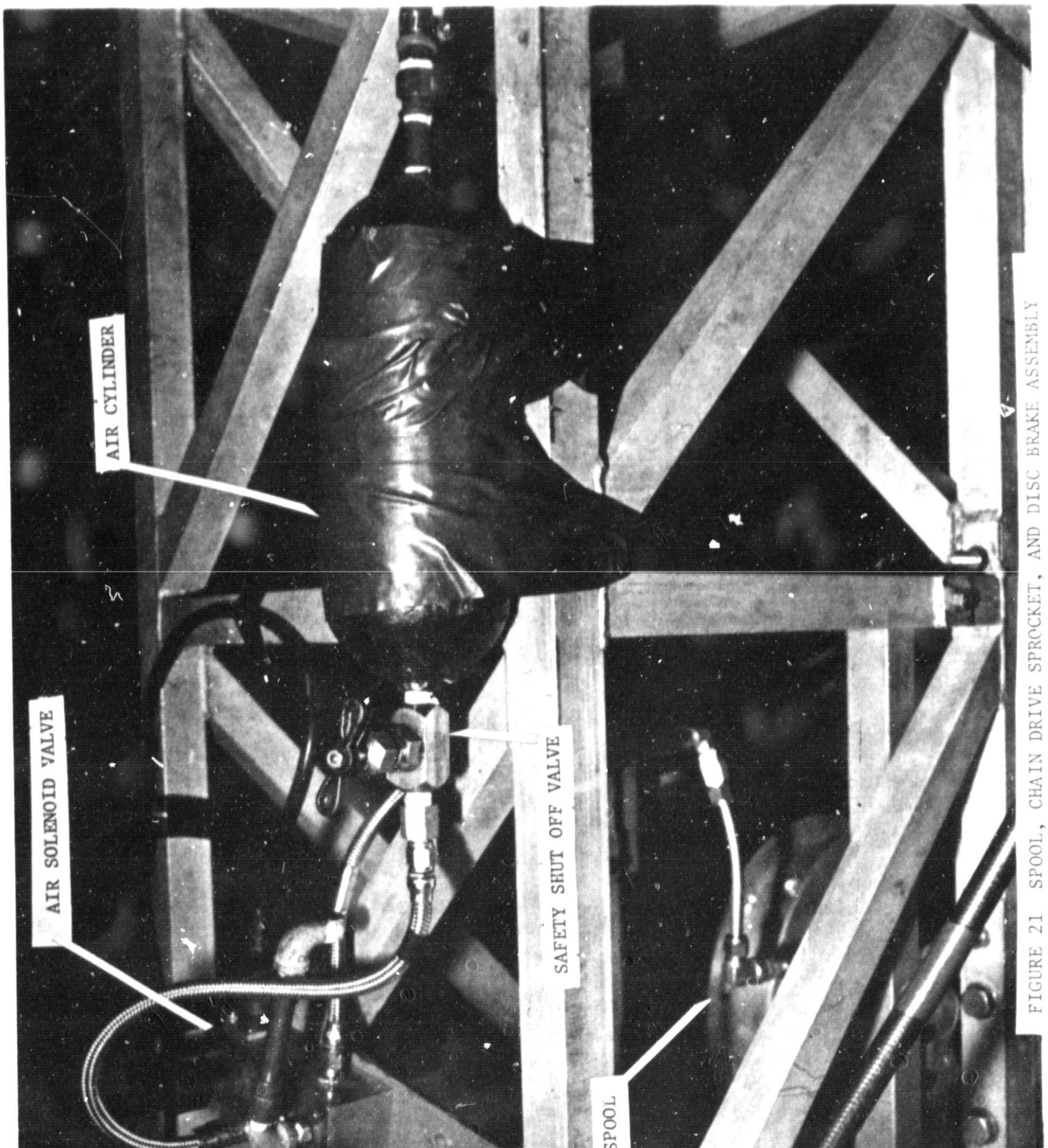

FIGURE 21 SPOOL, CHAIN DRIVE SPROCKET, AND DISC BRAKE ASSEMBLY

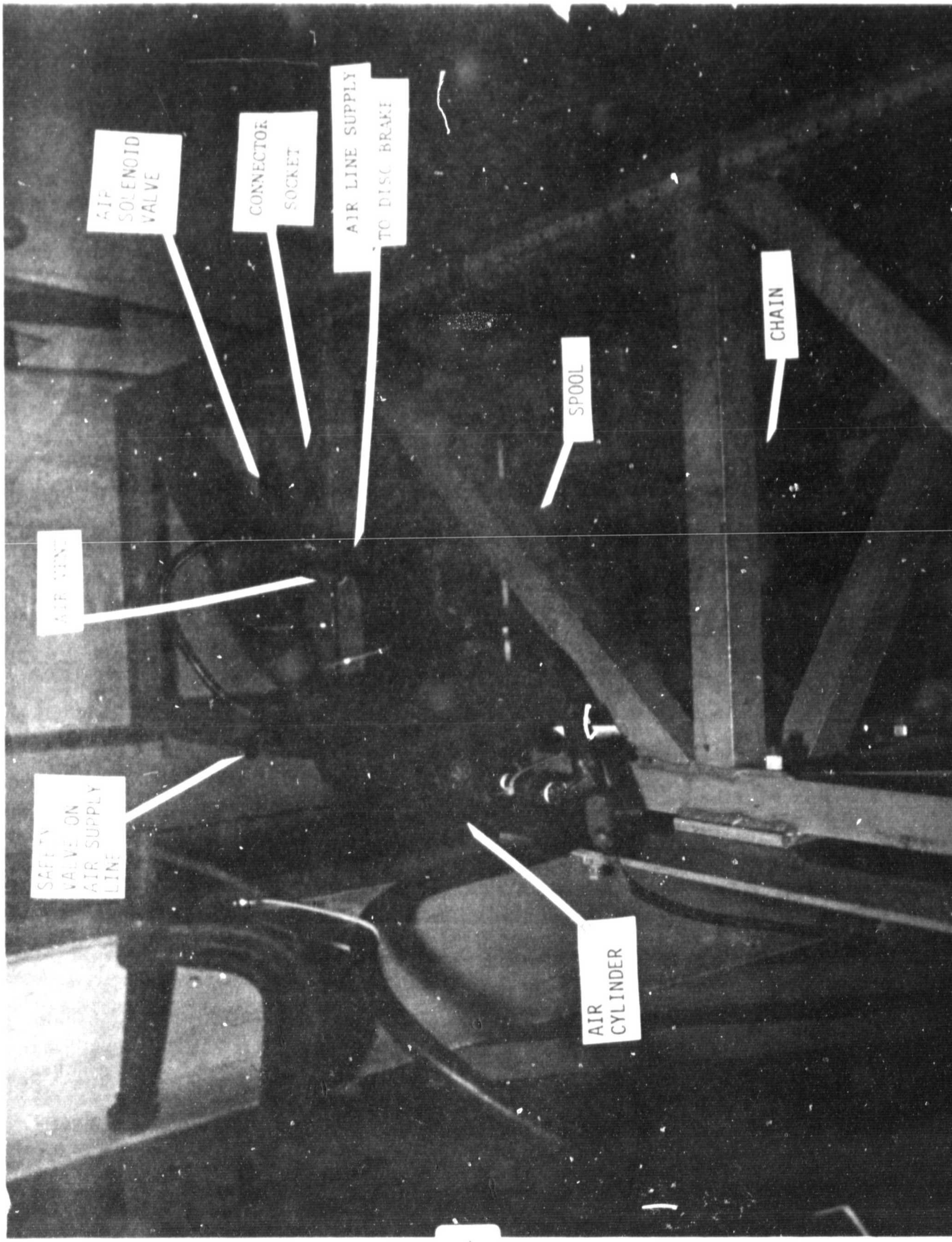

FIGURE 22 VIEW LOOKING DOWN AT CHAIN DRIVE ASSMEBLY

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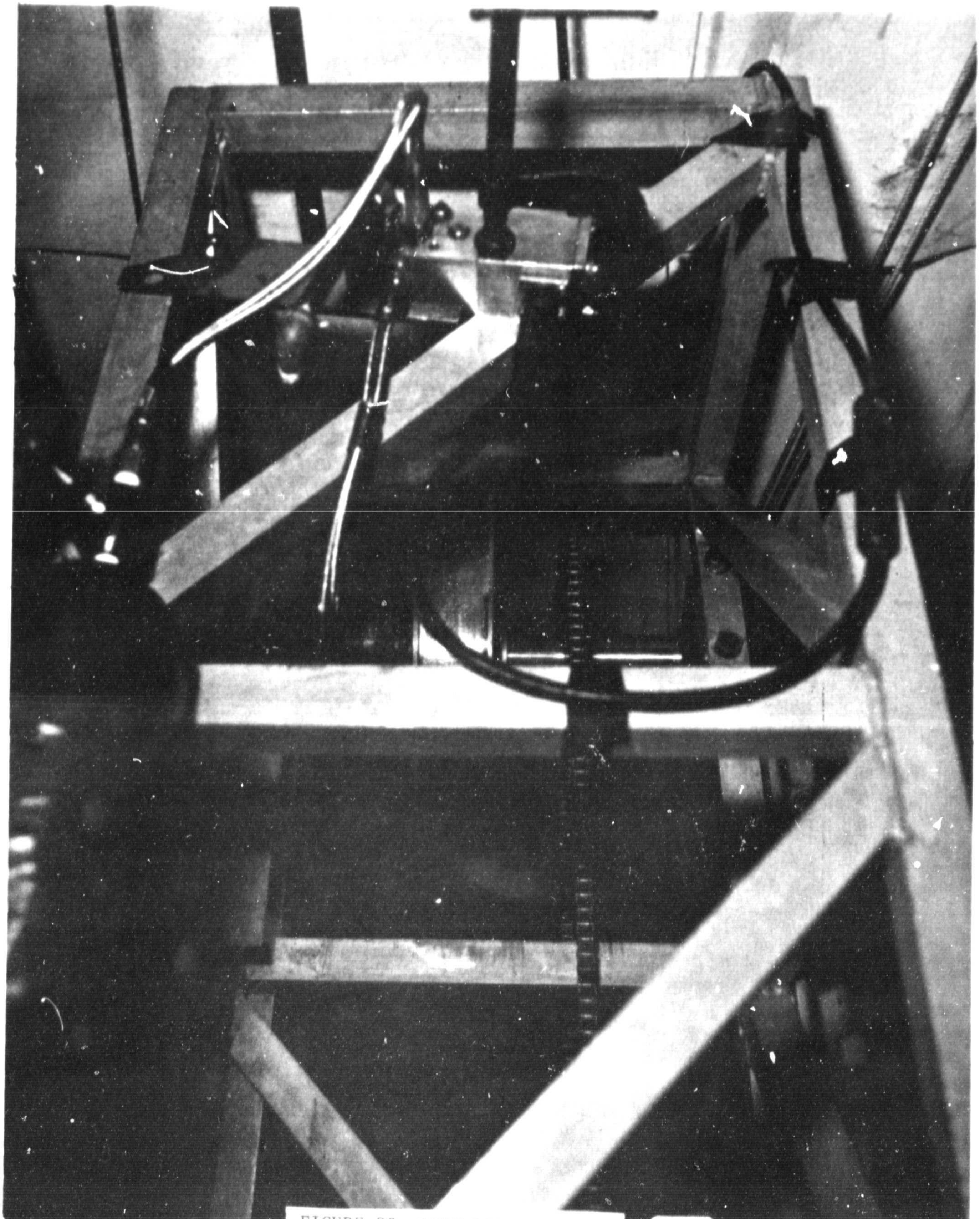

FIGURE 23 VIEW LOOKING DOWN

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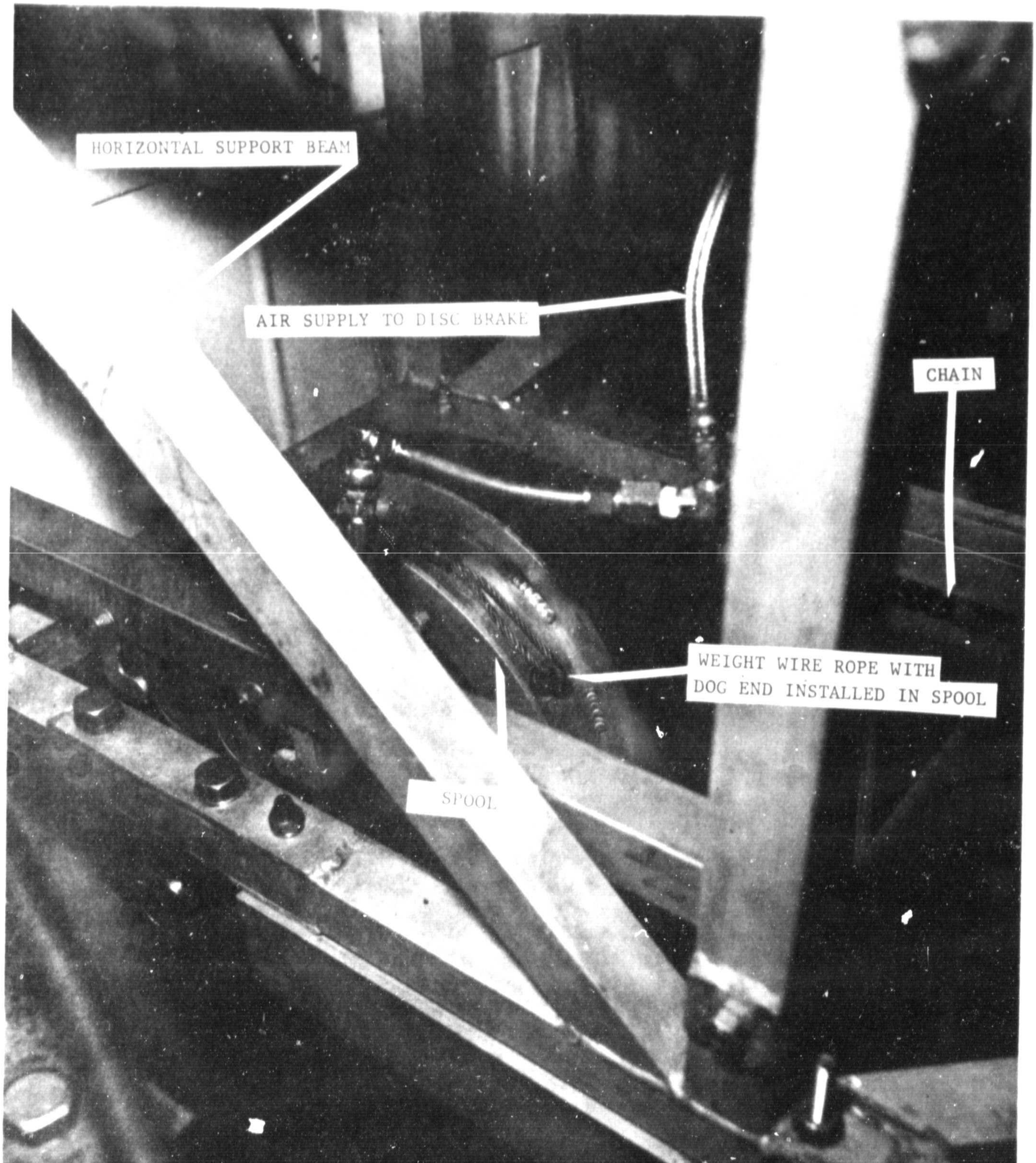


FIGURE 24 SPOOL, CHAIN DRIVE SPROCKET AND DISC BRAKE ASSEMBLY

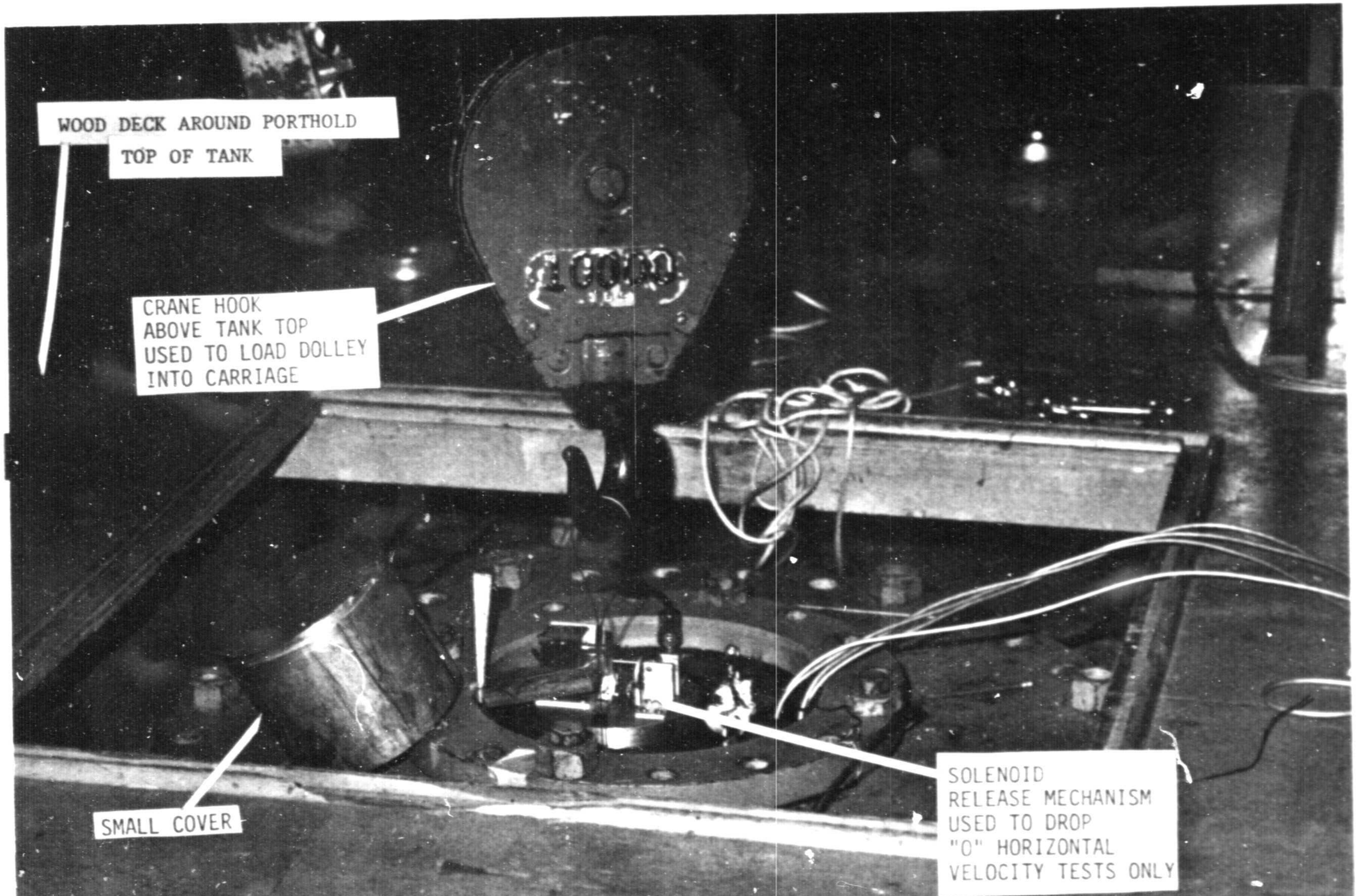


FIGURE 25 VIEW OF PORTHOLE WITH SPECIAL COVER IN PLACE

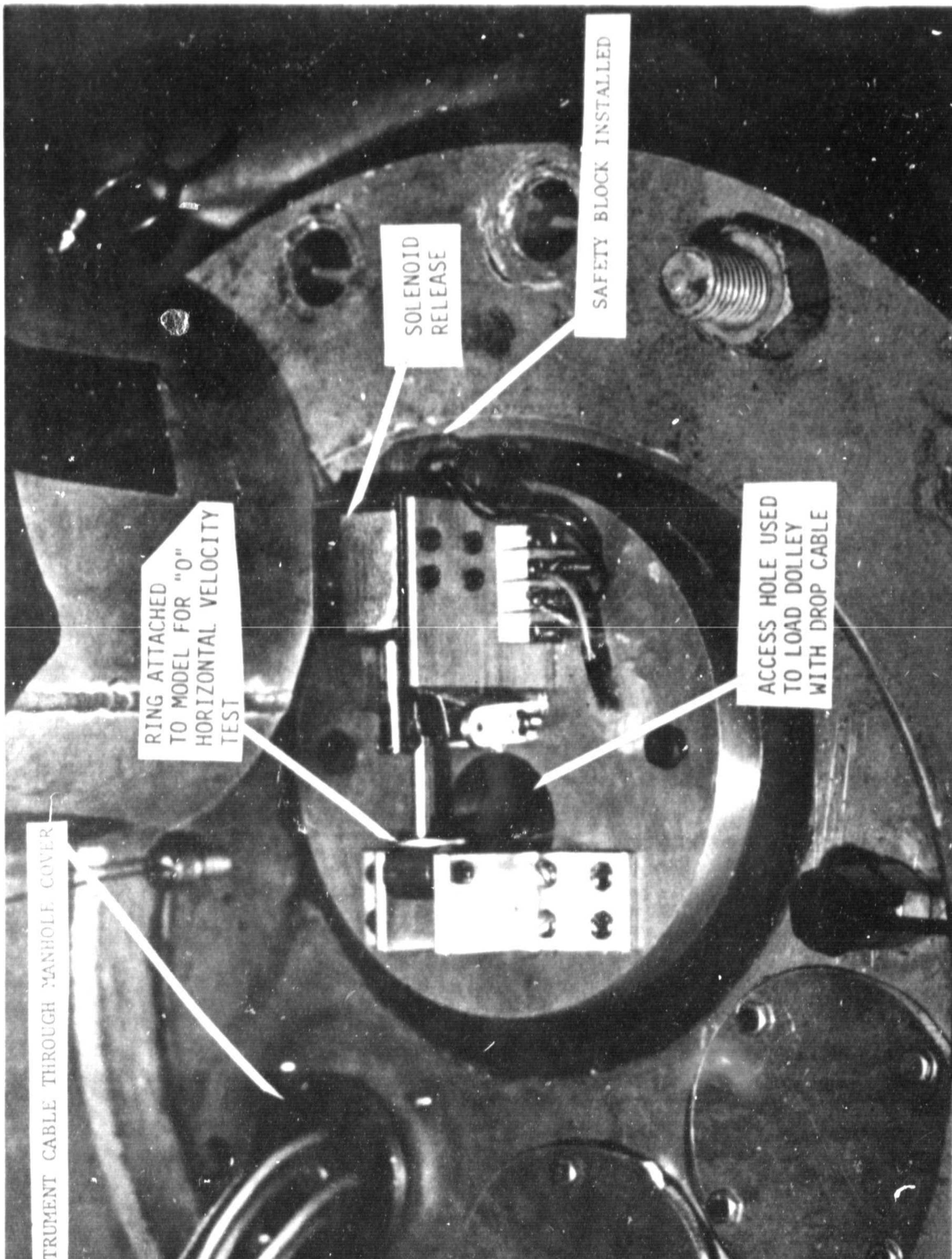


FIGURE 26 PORTHOLE WITH COVER REMOVED

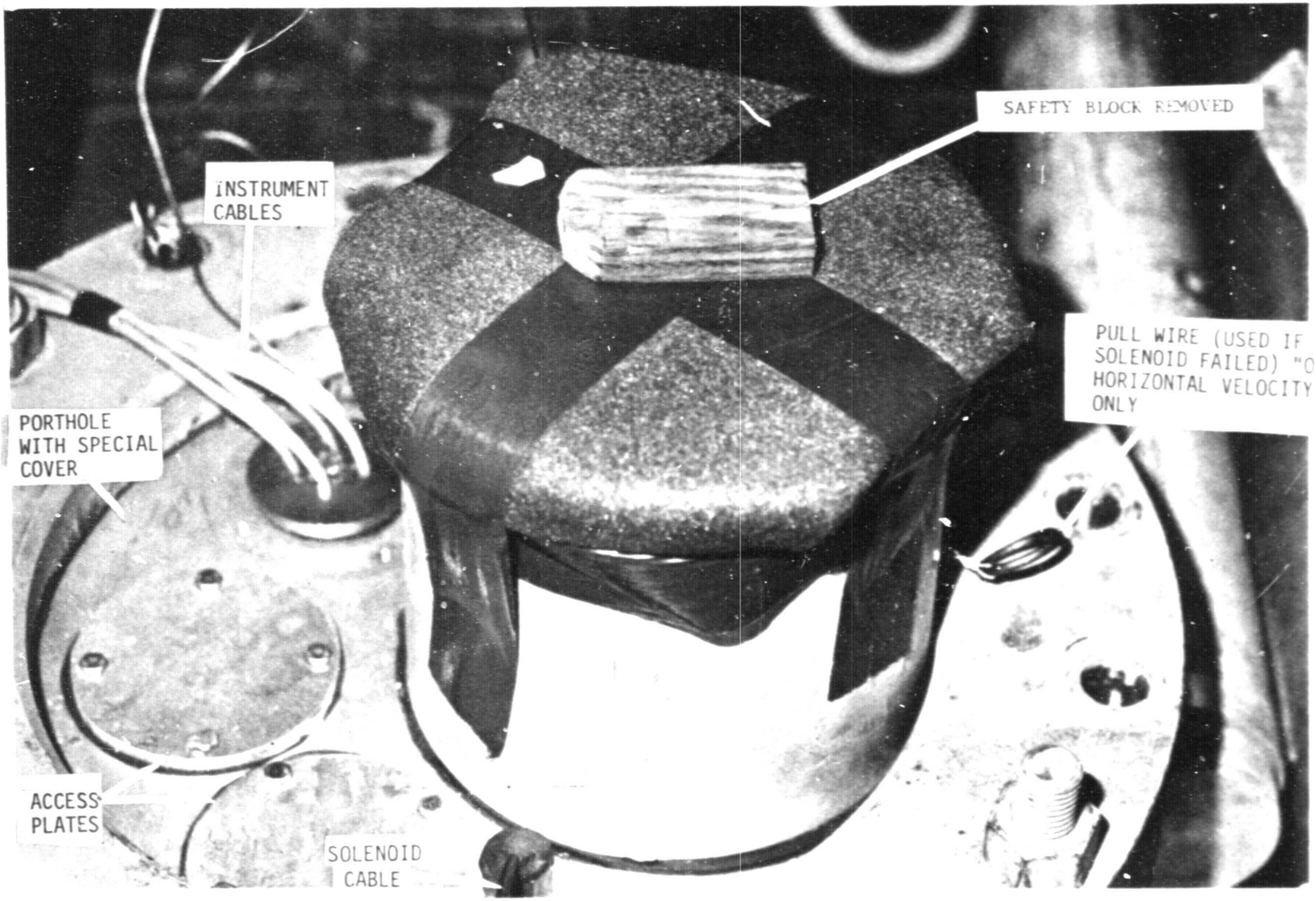


FIGURE 27 COVER IN PLACE

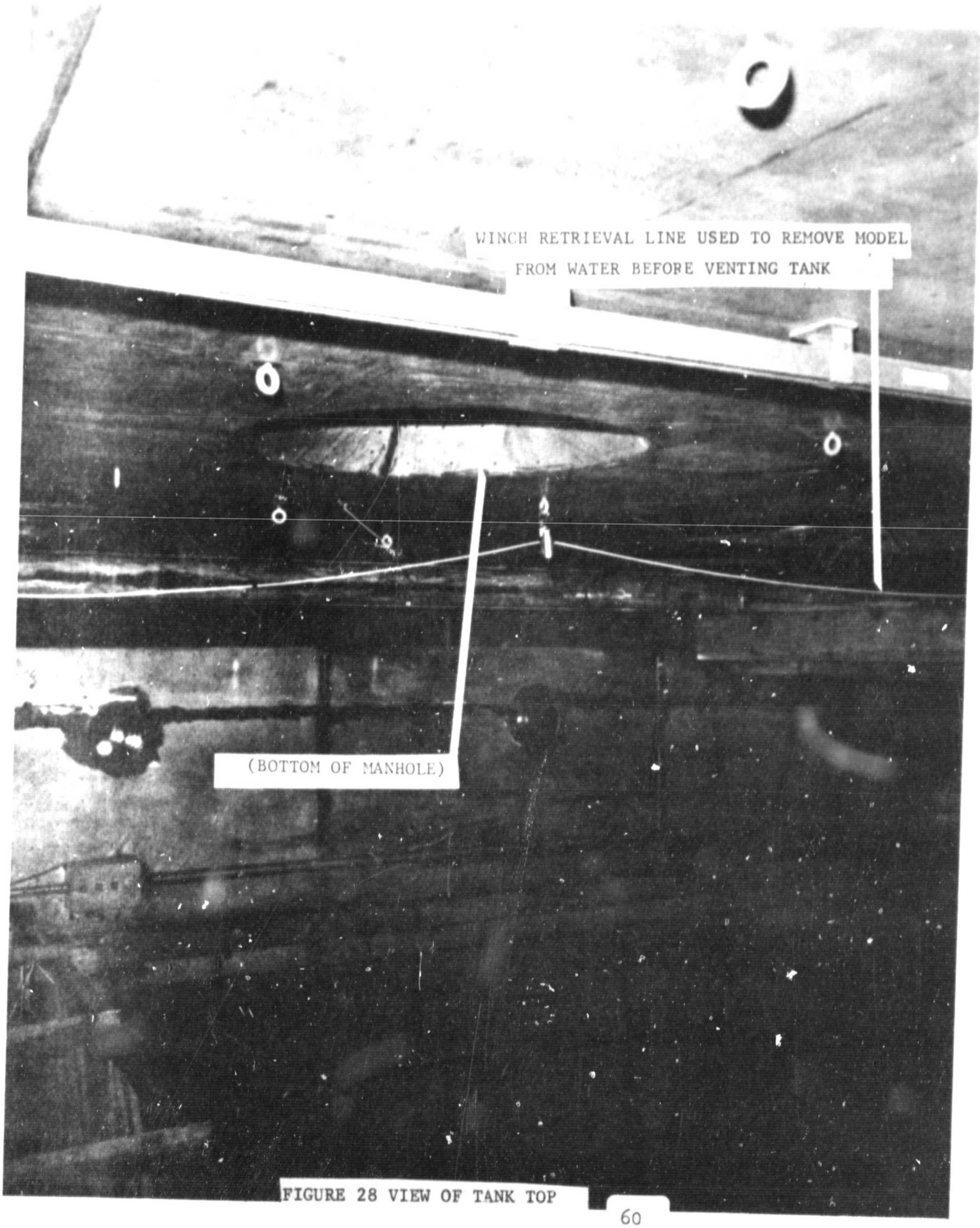


FIGURE 28 VIEW OF TANK TOP

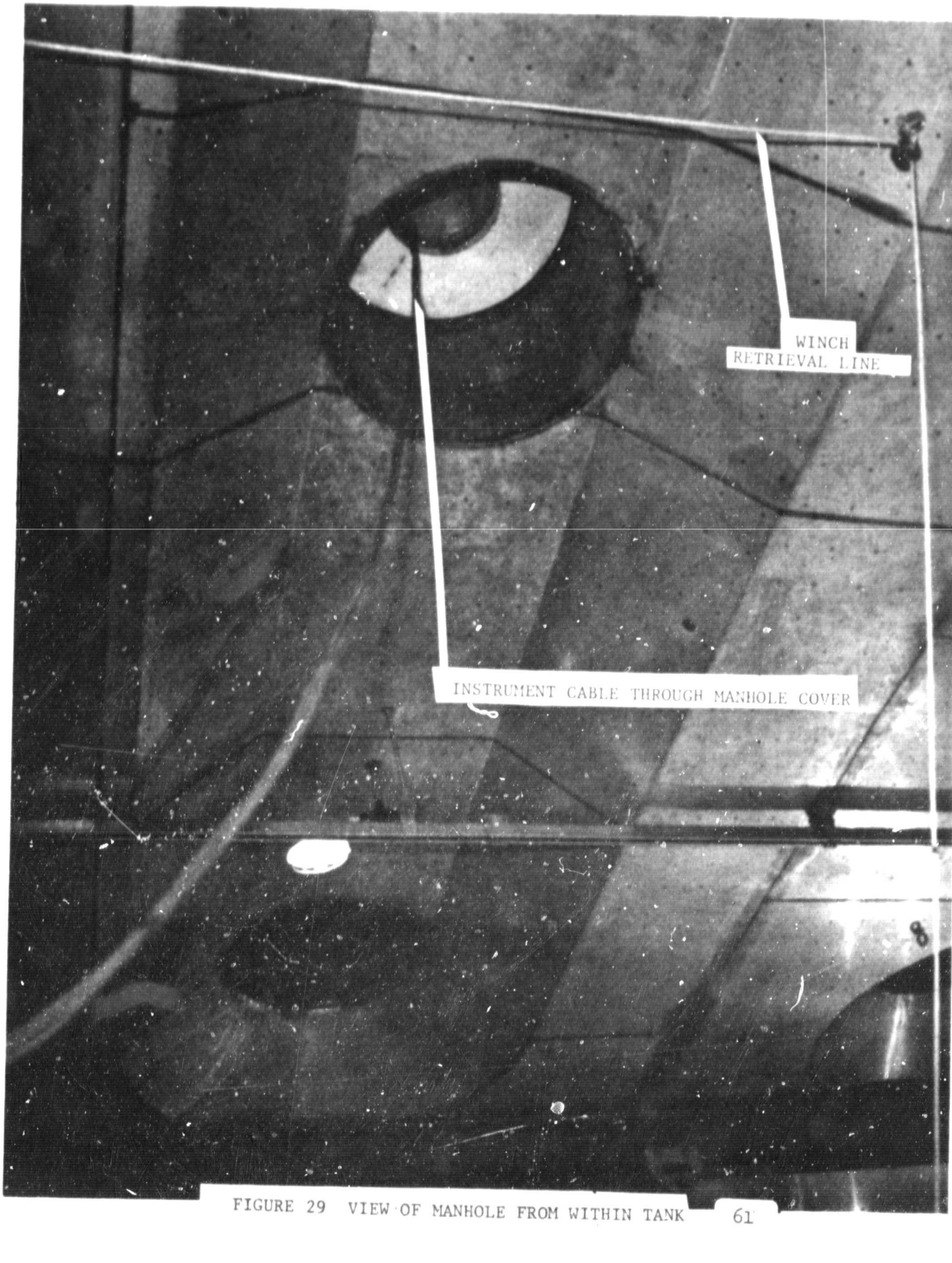


FIGURE 29 VIEW OF MANHOLE FROM WITHIN TANK

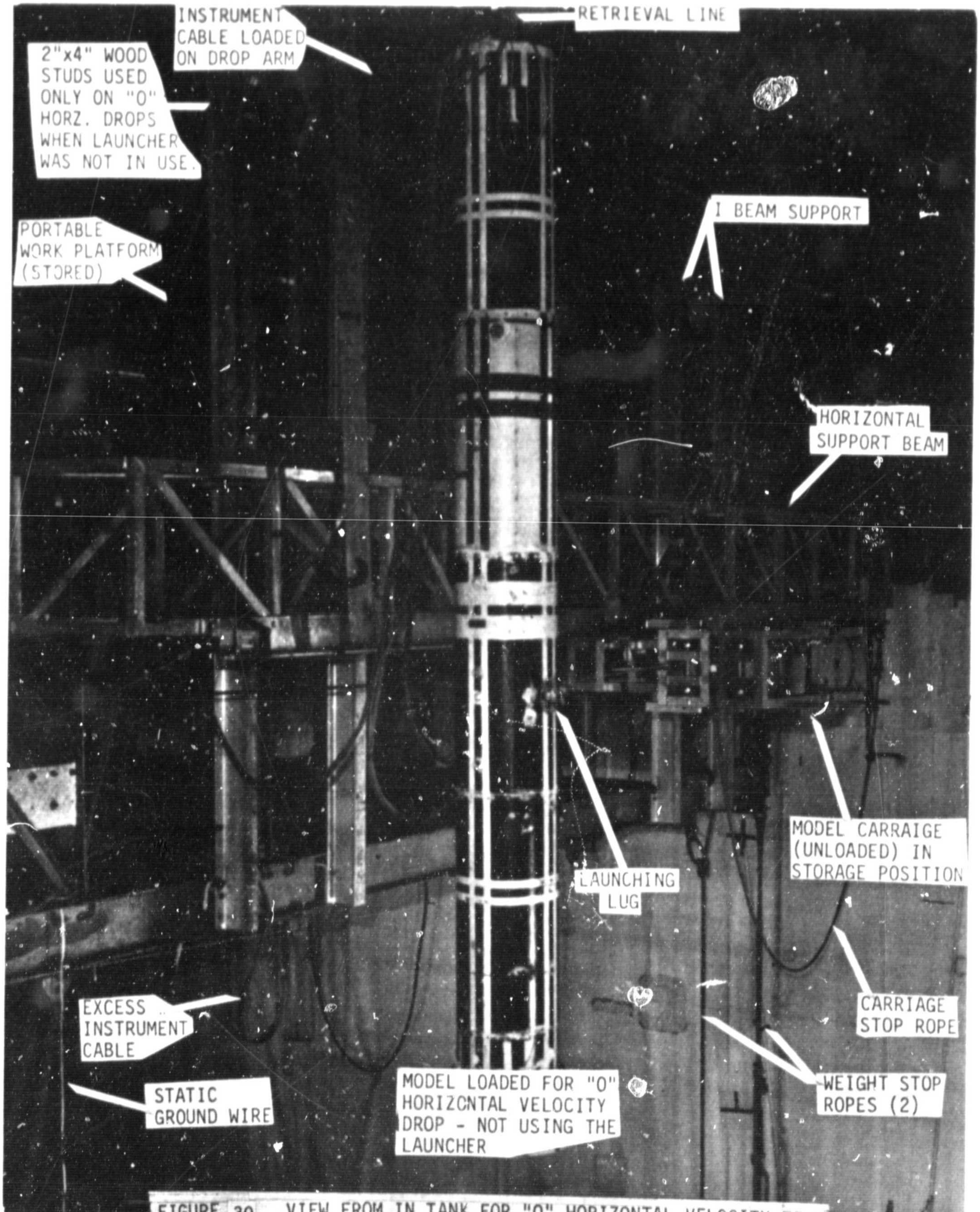


FIGURE 30 VIEW FROM IN TANK FOR "0" HORIZONTAL VELOCITY TEST

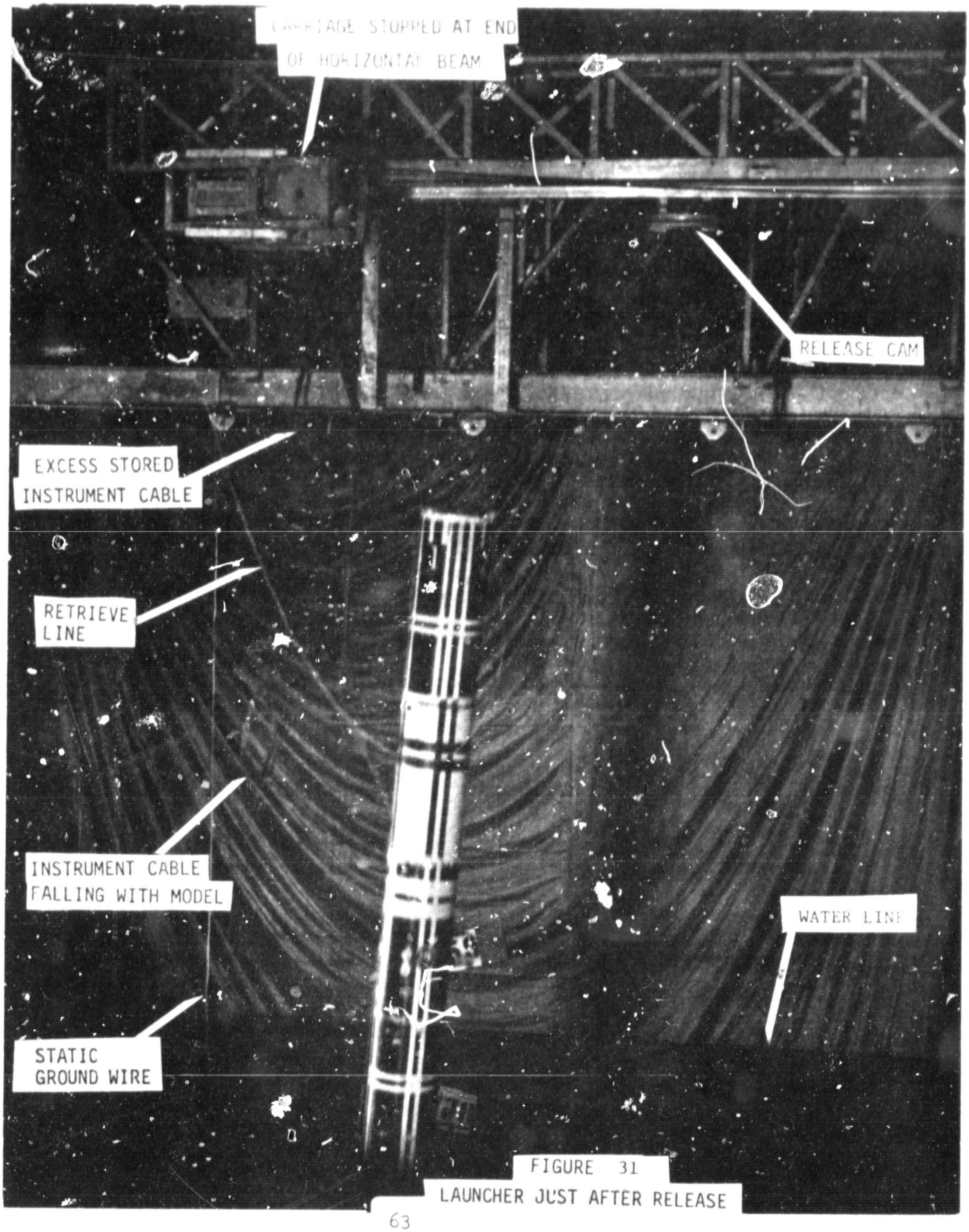


FIGURE 31
LAUNCHER JUST AFTER RELEASE

SECTION VIII- TRANSDUCER DATA REDUCTION

The first phase of data reduction was accomplished at the MSFC computation laboratory. The data tapes were demodulated, filtered with 5000 HZ low pass filters, digitized at 10,000 samples per second and converted to engineering units. Digital tapes containing the data from each test drop were forwarded to the Slidell Computer Center for further processing and plotting.

Transducer data in this report are presented in numerical order, 1 plot per page, for each test drop. Time zero on the plots is approximately .3 to .4 seconds prior to release. The zero reference time differs for each run. Approximately 50 milliseconds of data at 10,000 samples per second are presented for each measurement. Each time slice is chosen to illustrate the largest magnitude load event. All transducers are biased to zero at time zero. Units on the plots are g's for accelerations, psig for pressures, and pounds or inch pounds for nozzle loads.

It should be noted that the nozzle force data has not been corrected for balance interactions or for g loads. The interaction corrections are small, generally being less than 1%; the g corrections however, are a substantial magnitude and should be considered when using the data. These corrections are: 6.9 # normal/g pitch, 6.9 # axial/g axial, 5.865 in-# pitch/g pitch, and 8.988 in-# yaw/g axial. Figure 34 presents a typical set of data for Run #30.

The Appendix contains a complete set of all digitized data plots for all valid test runs.

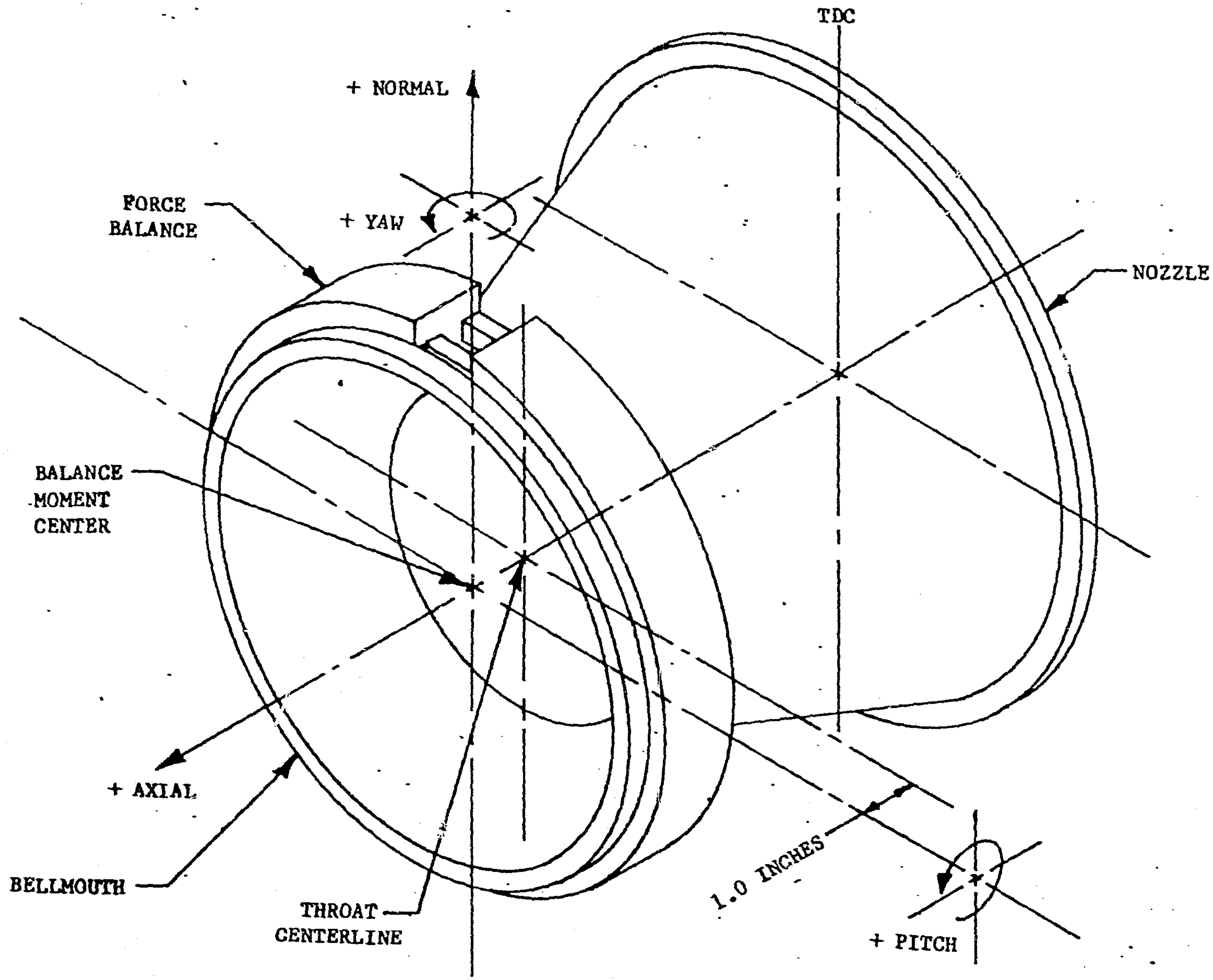
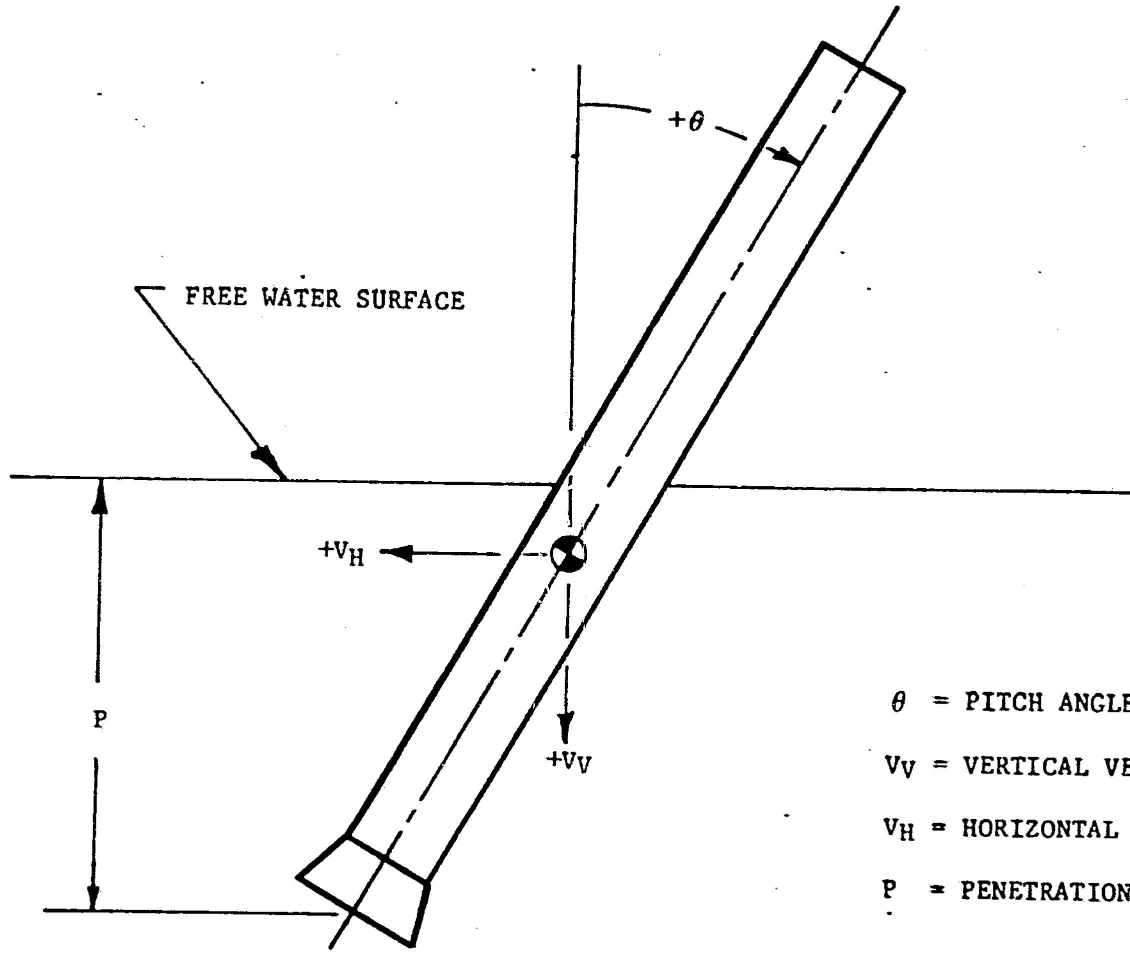


FIGURE 32 - NOZZLE FORCE BALANCE AXIS SYSTEM



θ = PITCH ANGLE, DEGREES

V_V = VERTICAL VELOCITY, FT/SEC

V_H = HORIZONTAL VELOCITY, FT/SEC

P = PENETRATION DEPTH, FEET

FIGURE 33 - MODEL AXIS SYSTEM

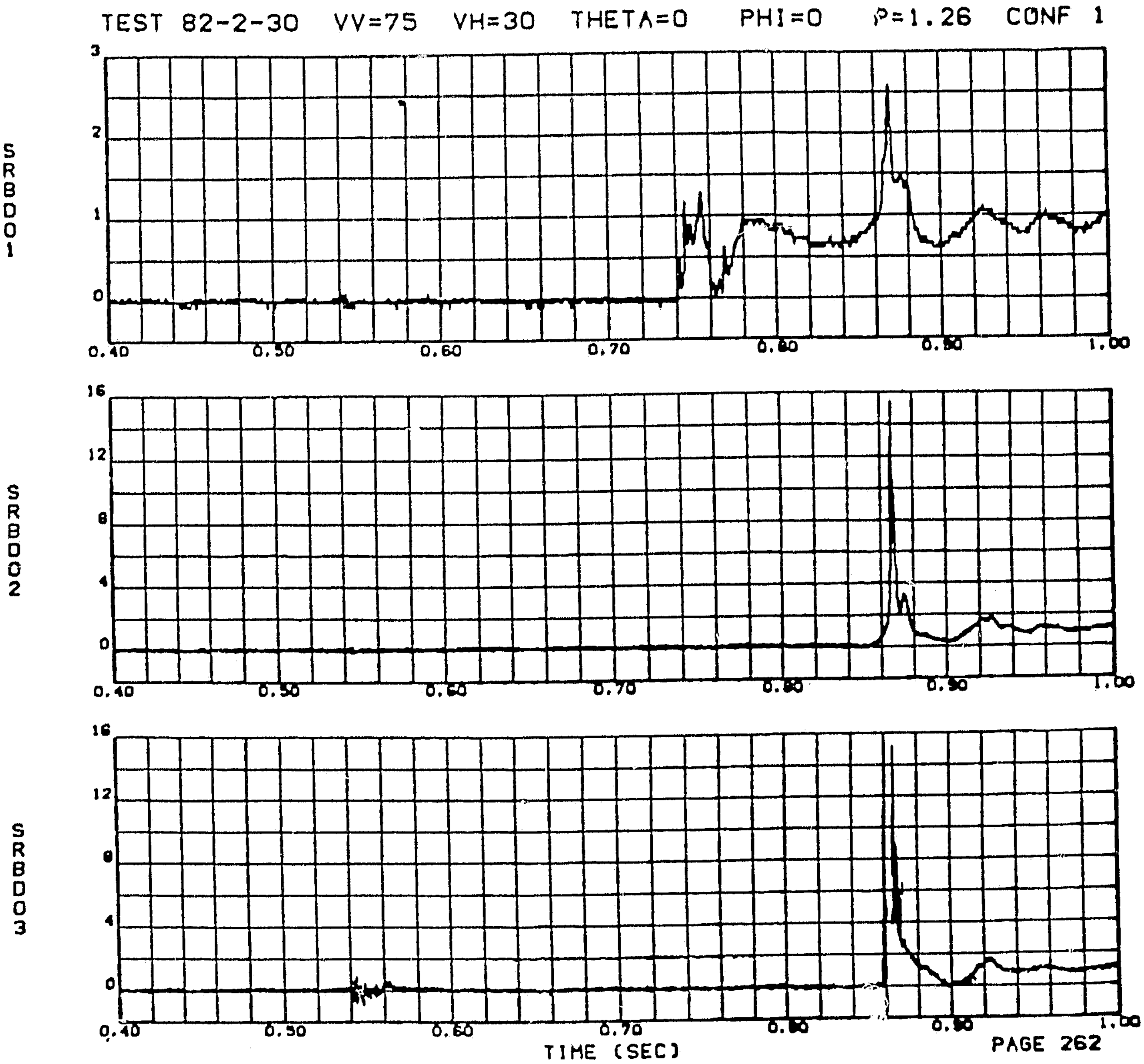


FIGURE 34 - DATA SAMPLE RUN #30

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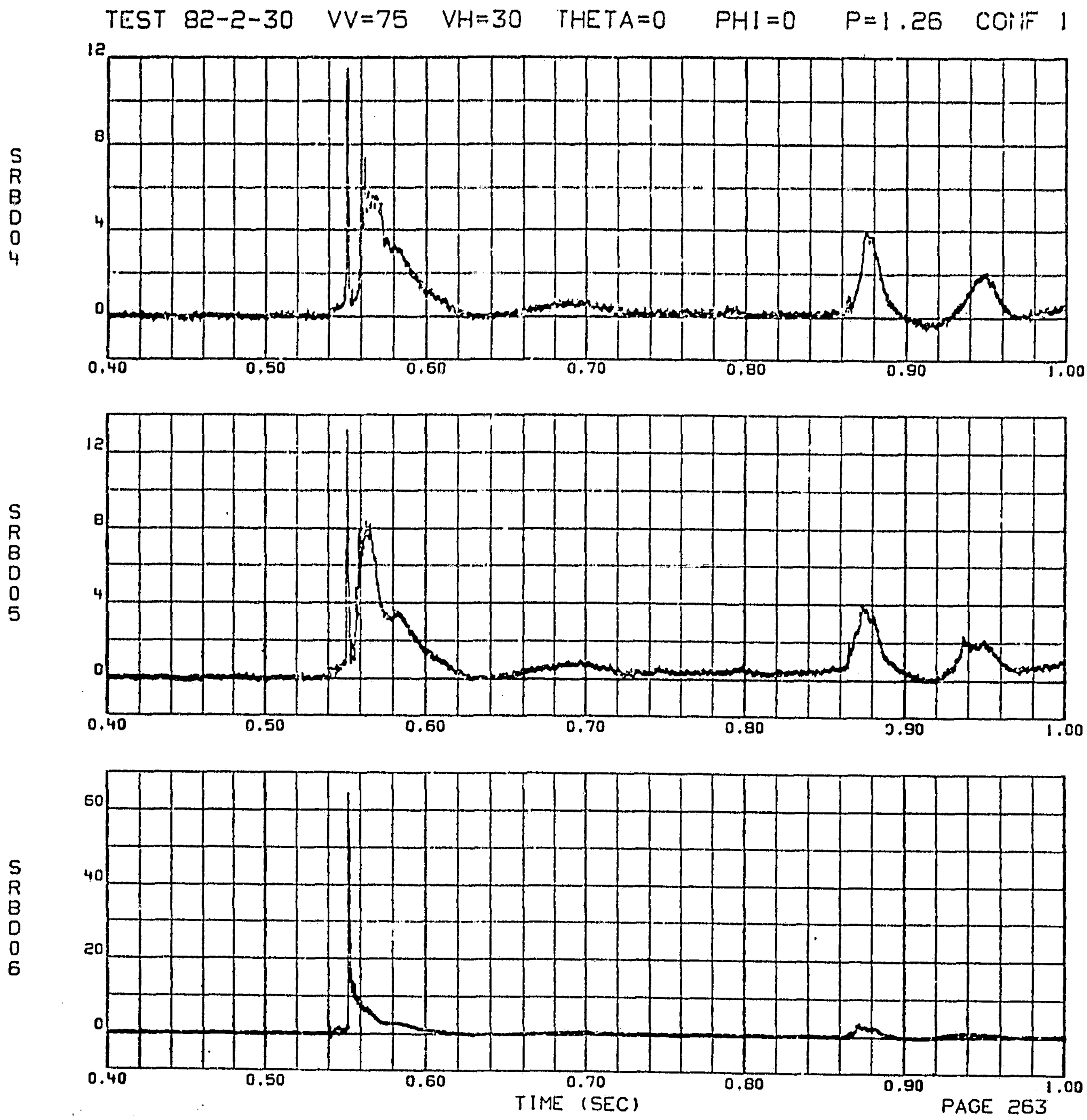

FIGURE 34 - DATA SAMPLE RUN #30 (CONT'D)

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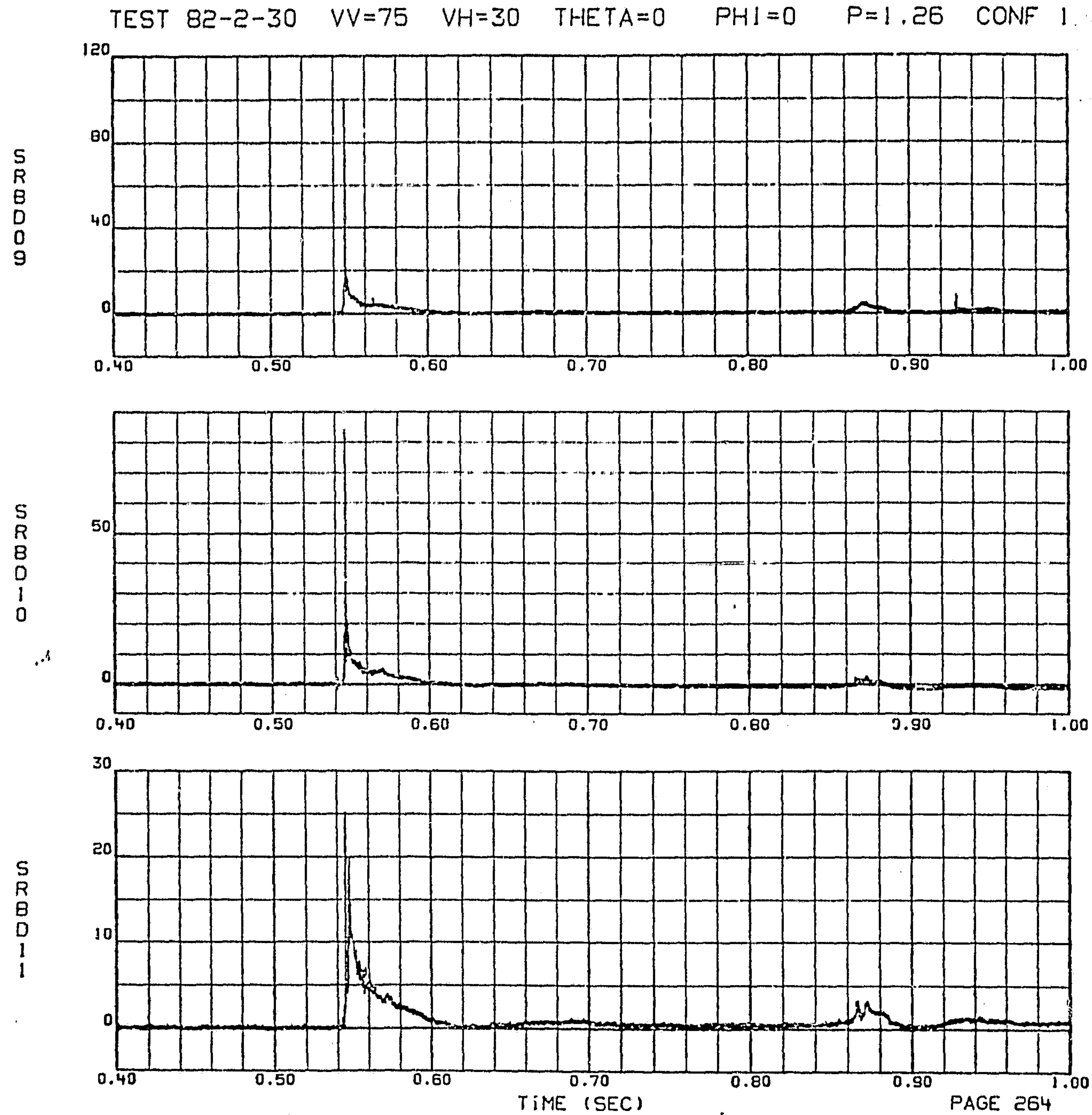

FIGURE 34 - DATA SAMPLE RUN #30 (CONT'D)

ORIGINAL PAGE IS
OF POOR QUALITY

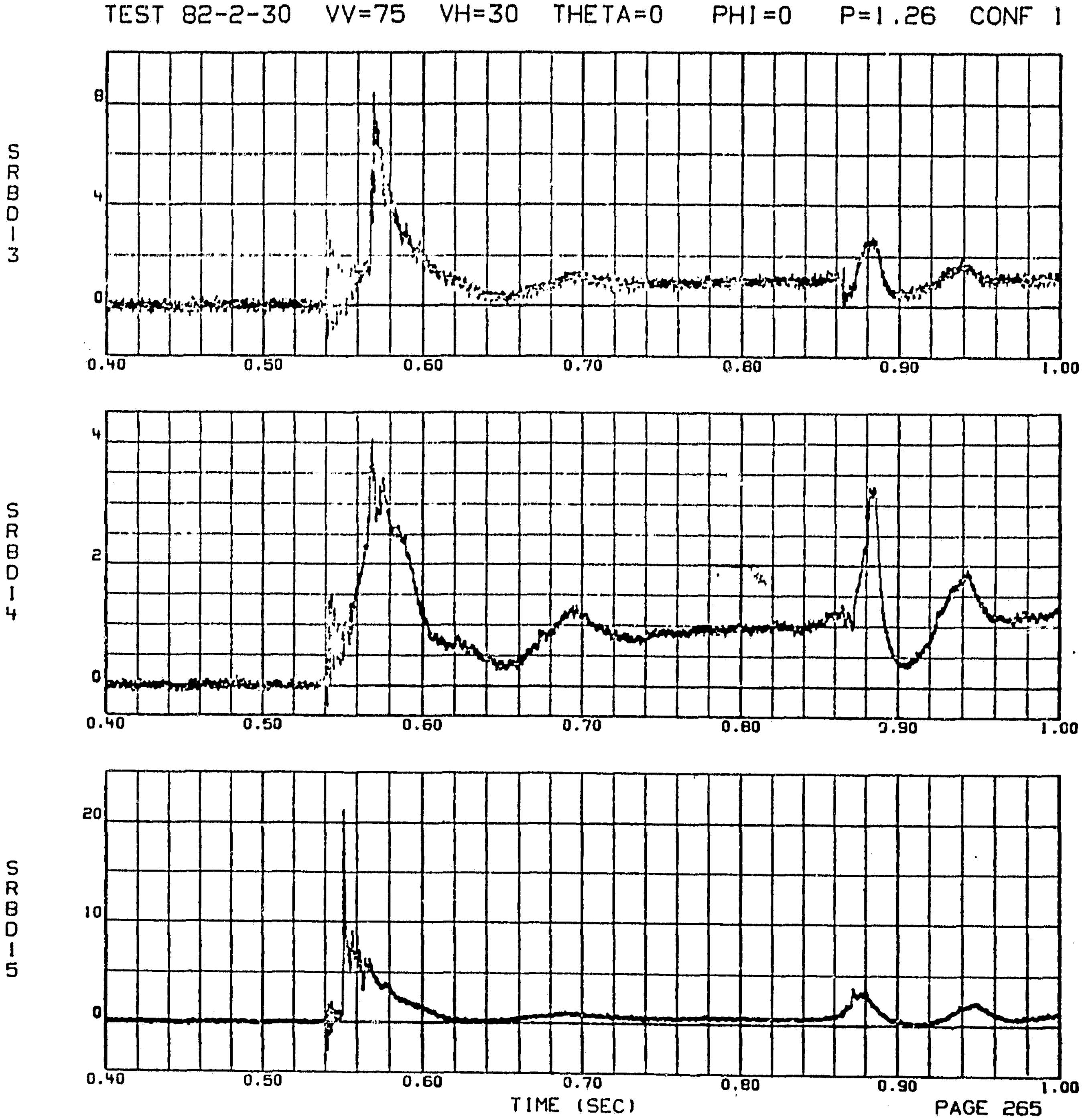

FIGURE 34 - DATA SAMPLE RUN #30 (CONT'D)

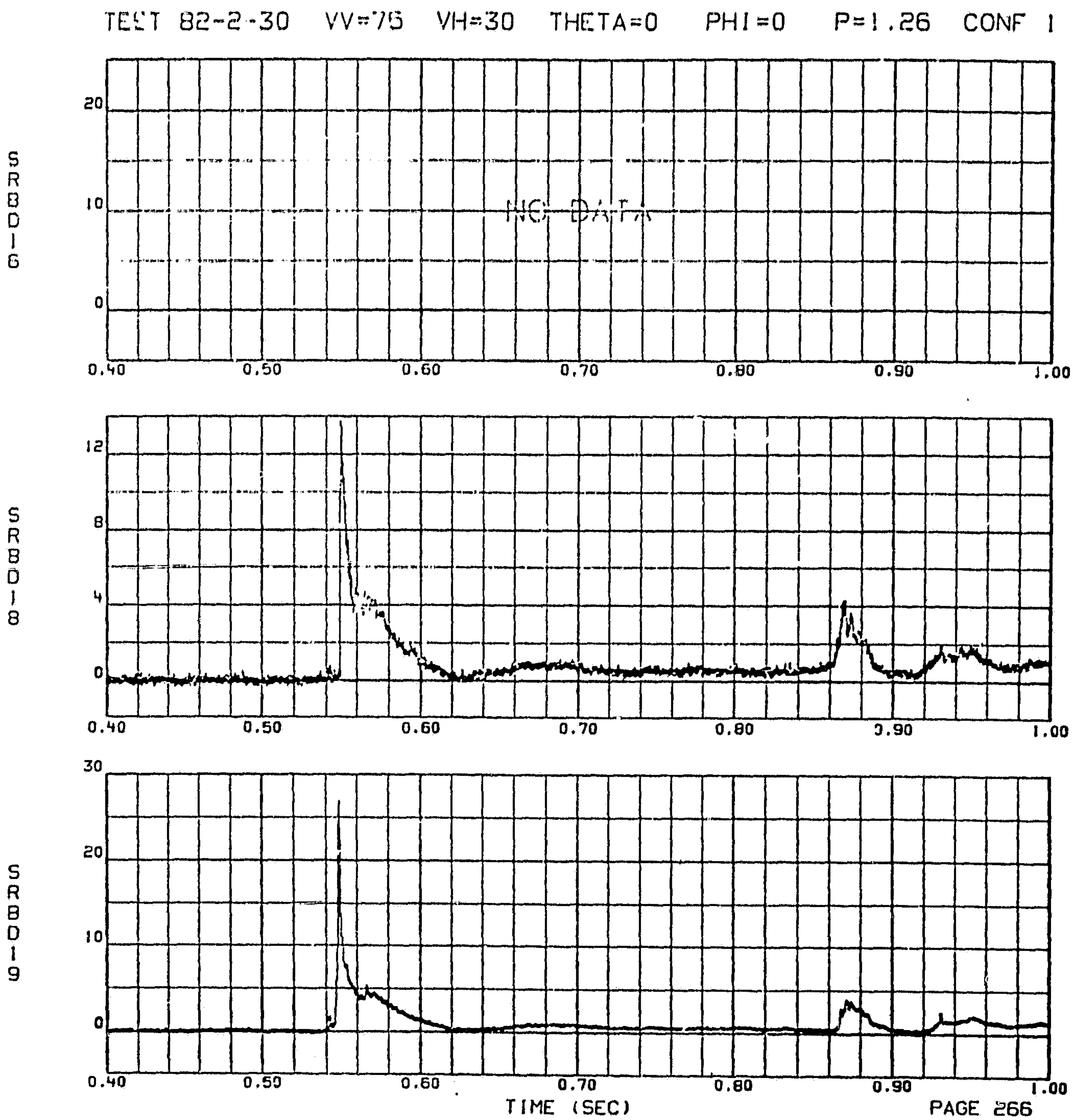

FIGURE 34 - DATA SAMPLE RUN #30 (CONT'D)

ORIGINAL PAGE IS
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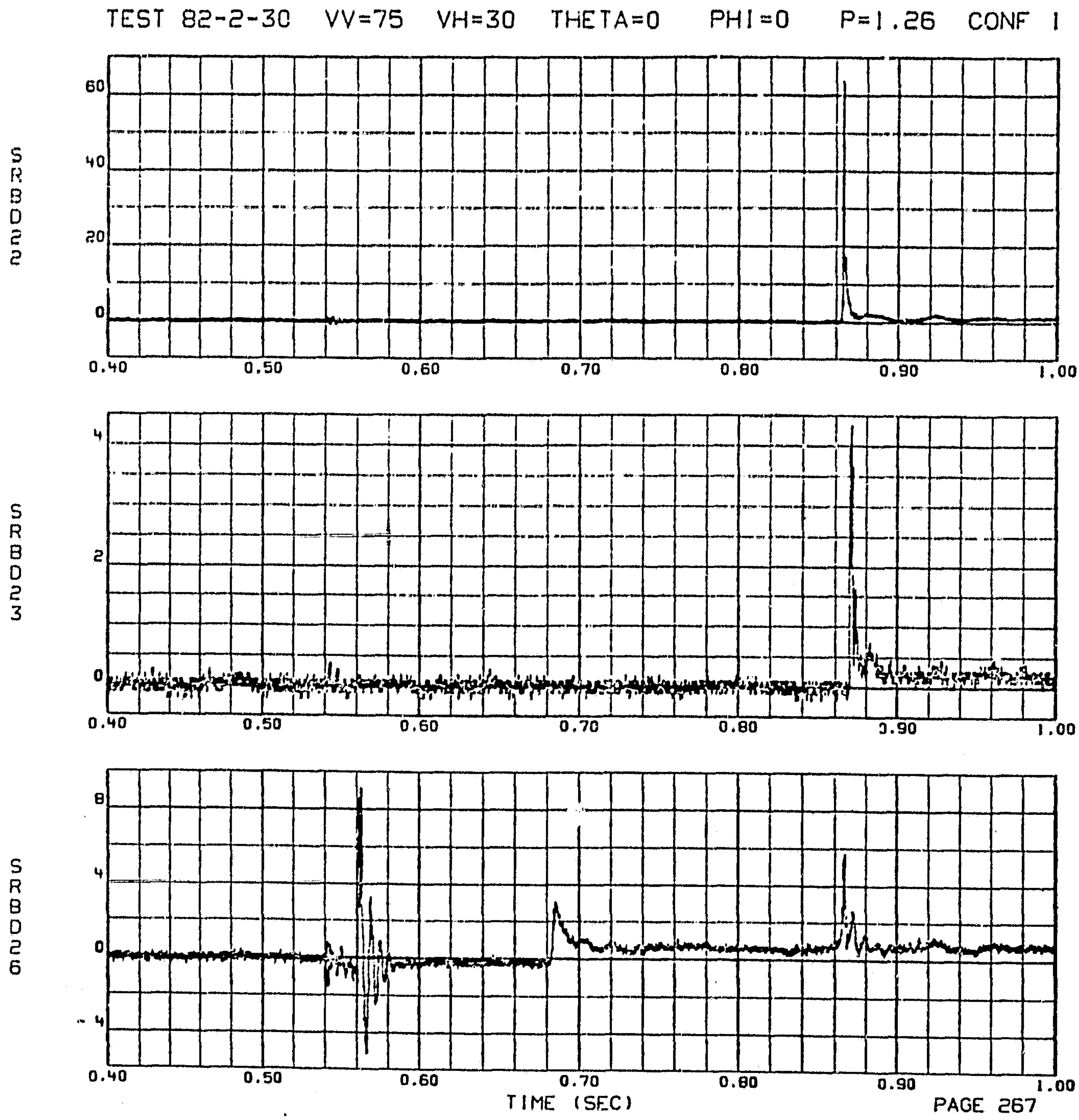

FIGURE 34 - DATA SAMPLE RUN #30 (CONT'D)

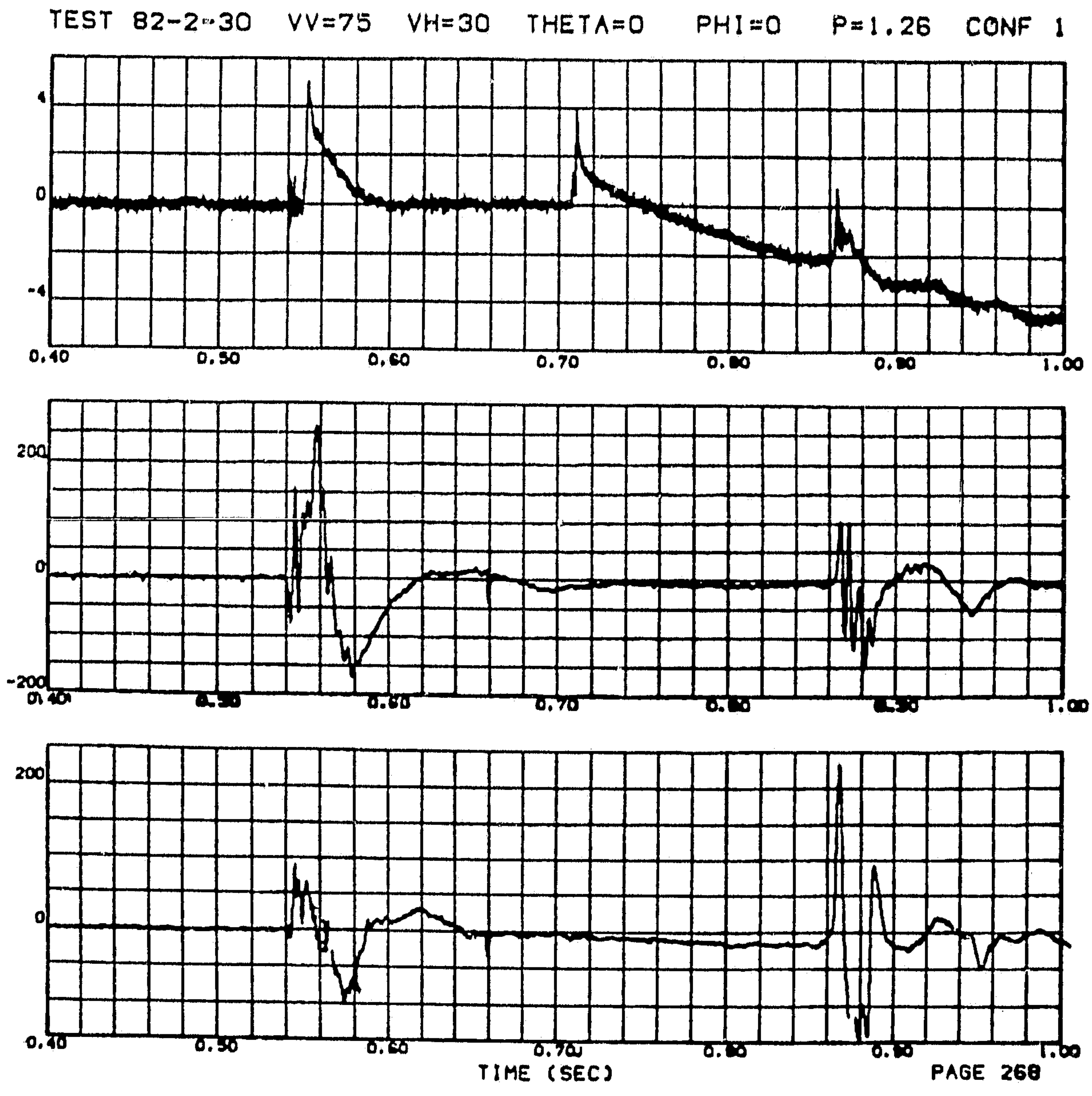

FIGURE 34 - DATA SAMPLE RUN #30 (CONT'D)

ORIGINAL PAGE IS
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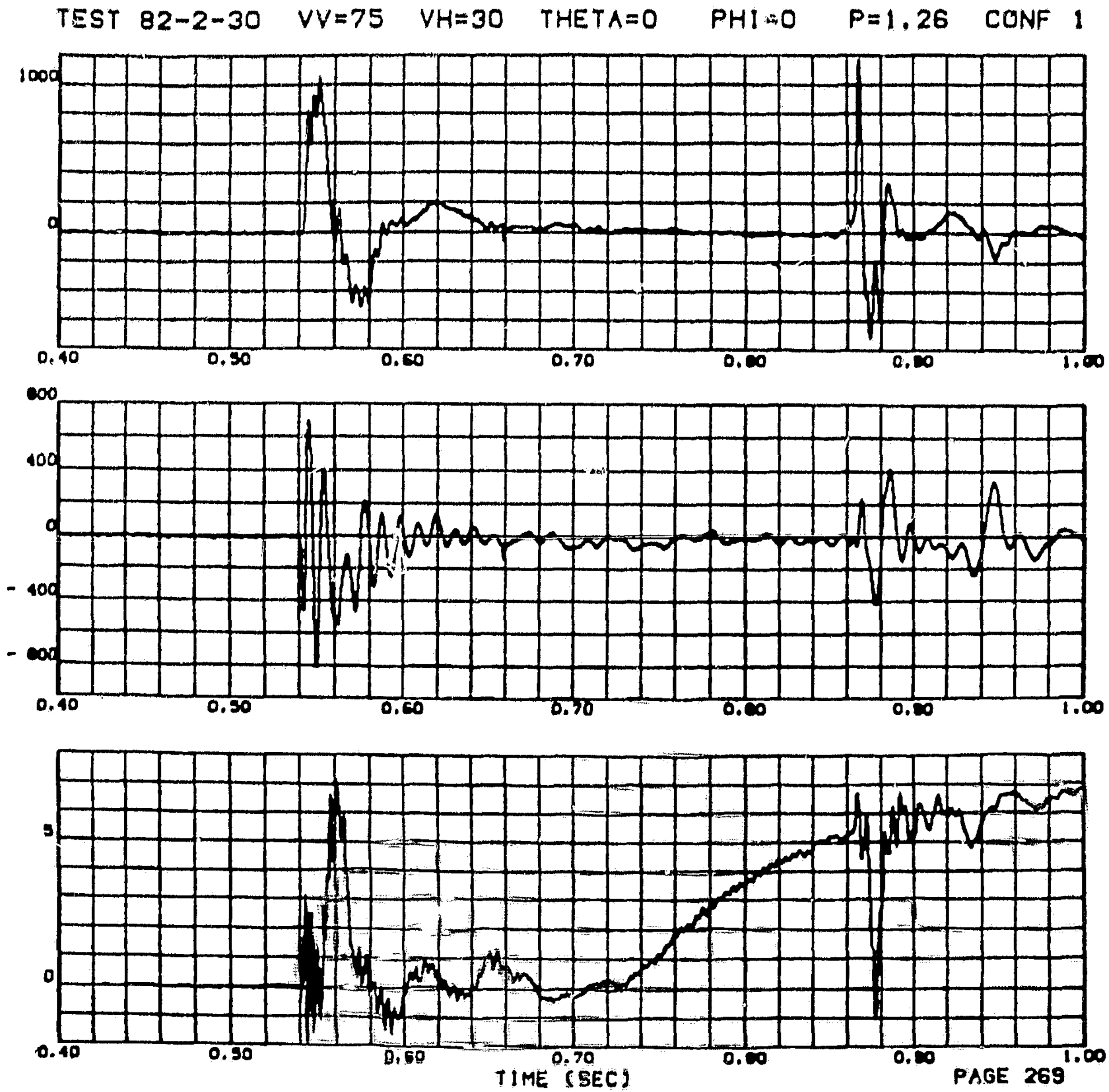

FIGURE 34 - DATA SAMPLE RUN #30 (CONT'D)

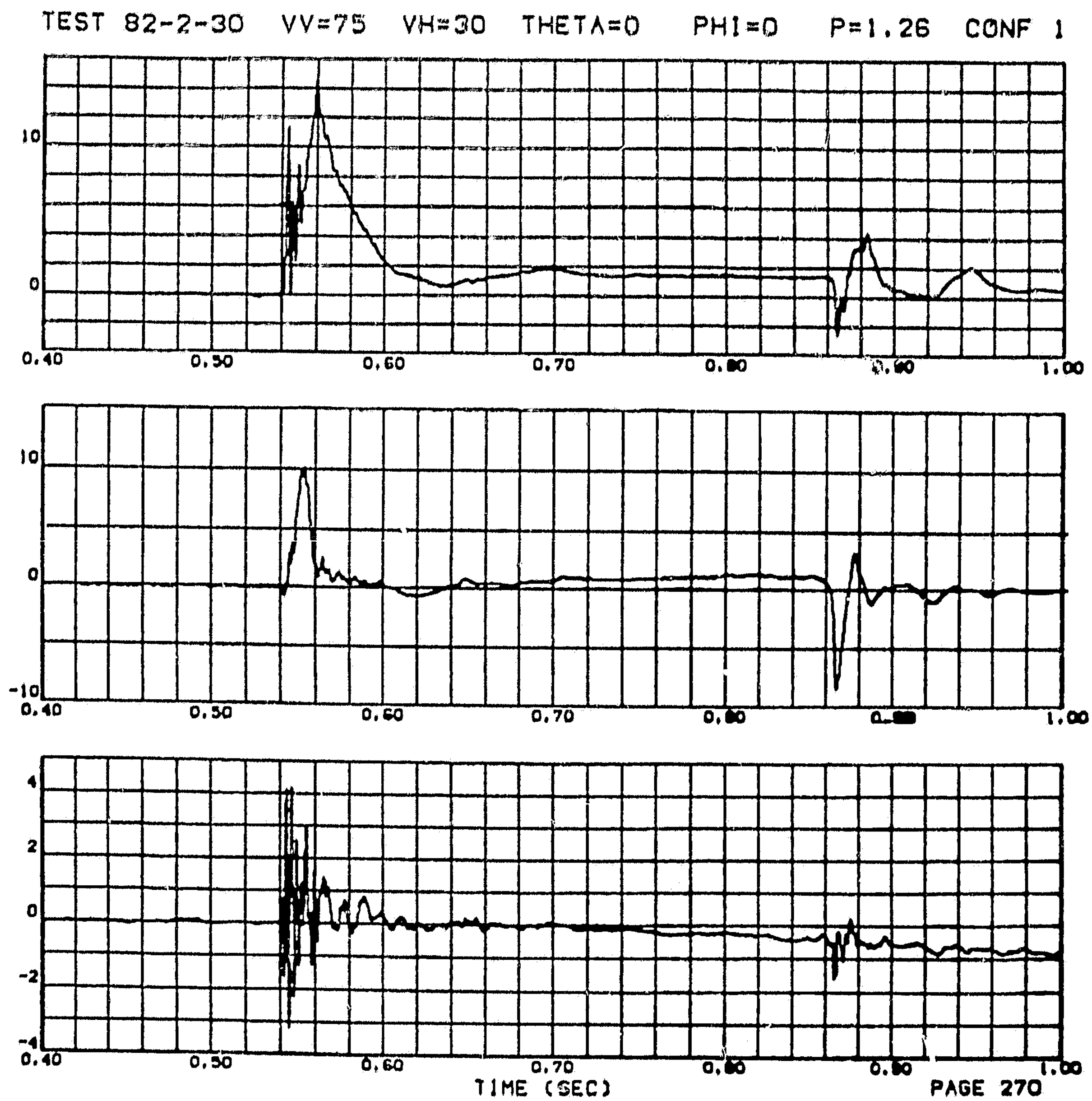

FIGURE 34 - DATA SAMPLE RUN #30 (CONCLUDED)

REFERENCES

1. Marshall Space Flight Center Document Test Requirements for SRB 8.56 Percent Scaled Model Water Impact Test Program, August 13, 1982, ED 22-103-82

2. Marshall Space Flight Center Document Test Requirements for SRB 8.56 Percent Scale Model Water Impact Test Program, January 7, 1982, ED 22-82-4

3. Marshall Space Flight Center Document Test Requirements for the SRB Aft Skirt Scale Model Water Impact Test Program, July 1981 ED 22-81-76.